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EFFECT OF CUTTING INTERVAL AND STAGE OF MATURITY ON THE DIGESTIBILITY AND YIELD OF ALFALFA [1, 2]

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THE goal of the alfalfa producer is to obtain the largest yield of high quality forage consistent with reasonable stand survival. Peterson and Hagan (1953) demonstrated that the largest total yield of dry matter for the season was obtained when alfalfa and grass were clipped at a five-week interval in comparison with either two-, three- or four-week cutting intervals. Jones *et al.* (1953) have shown that the dry matter yield per acre increases per cutting up until the time of full bloom which may be as long as 50 to 60 days after the previous cutting; but from the quality standpoint and seasonal production per acre, the protein and carotene content decline and the fiber and lignin increase as the alfalfa becomes more mature and as the cutting interval is lengthened.

Numerous investigations have been conducted on the effect of cutting time on the feeding value of the hay, seasonal yield, and survival of the stand. Dawson *et al.* (1940) have reviewed the early literature on this subject. Sotola (1927) summarized the recommendations available at that time as follows: "Recommendations favor the early bloom stages—7 for 1/10 bloom, 4 for early bloom, 2 for 1/4 bloom, 4 for 1/3 bloom and 2 for full bloom". The difficulty in assessing this earlier work is that no definite system was used in describing stage of maturity. Kivimäe (1959) has recently reviewed the literature on the effect of maturity on chemical composition and digestibility of forage crops. He reports on the effect of cutting, season and chemical composition on digestibility of red clover and timothy.

Reid *et al.* (1958) discussed the influence of cutting date on digestibility based on the Cornell studies which demonstrate the superiority of early-cut forages over those harvested late. They also point out the fallacy of using dry matter yield as a single index of productiveness.

The studies reported in this paper were designed to determine the effect on yield and digestibility of alfalfa cut at varying calendar intervals as well as according to definitely described stages of maturity. Yield of dry matter and protein from alfalfa cut at four stages of maturity over three seasons is reported as well as the effect on yield during the fourth season when all plots were cut at the same stage of maturity.

[1] This research was supported in part by a grant from the American Dehydrators Association, Kansas City, Missouri.
[2] The authors wish to express their appreciation for technical assistance to A. R. Terrill and J. L. Hull of the Department of Animal Husbandry.
[3] Department of Animal Husbandry.
[4] Department of Agronomy.

Experimental Methods

Studies on the Effect of Cutting Interval Upon Yield and Digestibility. When alfalfa is used for pasture or for soilage, a definite schedule of cutting or pasture rotation is essential to a sound forage production pro-

TABLE 1. STAGE OF MATURITY OF ALFALFA WHEN CLIPPED

Harvest dates		Cutting interval			
		Three weeks	Four weeks	Five weeks	Six weeks
April	14	First cutting removed			
	21				
	28				
May	5	Pre-bud			
	12		Early bud		
	19			9% bloom	
	26	Pre-bud			65% bloom
June	2				
	9		Bud		
	16	Pre-bud			
	23			53% bloom	
	30				
July	7	Pre-bud	14% bloom		Full bloom
	14				
	21				
	28	Pre-bud Early bud		60% bloom	
August	4		20–30% bloom		
	11				
	18	Pre-bud			Full bloom
	25				
September	1		Late bud	33% bloom	
	8	Pre-bud			
	15				
	22				
	29	Pre-bud	Bud		20% bloom
October	6			Bud	
Seasonal average		Pre-bud	5% bloom	31% bloom	71% bloom

gram with properly scheduled irrigation and recovery periods. The first study was therefore on a calendar basis. Seasonal differences in yield will result in an excess of forage during the fast growing season on this type of schedule for pasture or soilage, but the surplus can be either harvested for silage or hay and fed later.

For this study a uniform second-year stand of California Common alfalfa was selected. The first crop of hay was harvested from the tract on April 14, 1954 and discarded. Following the removal of the first crop,

the area was divided into 24 blocks, 20 × 25 ft. in size and randomized into four treatments with six replications. The clipping schedule and the stage of maturity of the alfalfa at each clipping are shown in table 1. The alfalfa was irrigated eight times during the course of the experiment so water was not a limiting factor at any time.

On the morning of each cutting date, six 25-culm samples (one from each replication) were taken per treatment. The stage of maturity was determined by counting the number of culms which had reached a particu-

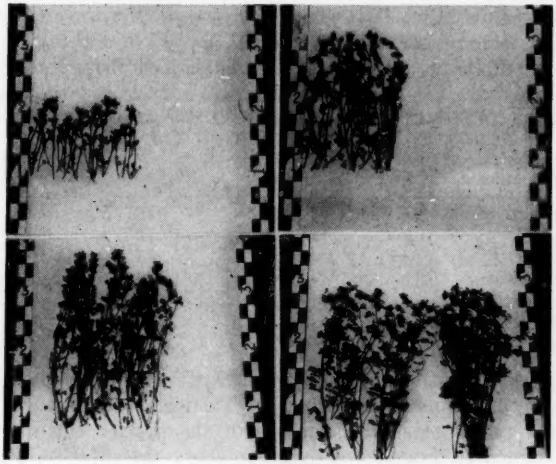

Figure 1. Stages of maturity of alfalfa.
Upper left: Pre-bud.
Upper right: Bud.
Lower left: 1/10 bloom.
Lower right: 1/2 bloom.

lar stage of growth and were described as pre-bud, bud or a percent of bloom. For example, if 10 culms out of a 100-culm sample showed flowers, it was called 10% bloom (figure 1). The six samples were oven-dried and analyzed for carotene and nitrogen. In the afternoon following sampling, the plots were mowed with a regular mowing machine. For yield determination, a six-ft. swath, 20 ft. in length, was cut and weighed for total green weight and a five-lb. sample from each replicate was retained for dry matter determination. The remaining material from each replication was collected on canvas and dried in the shade for the digestion trials. The green material was turned as often as necessary to insure proper curing. When dry enough it was chopped and further dried until completely cured and then stored in paper bags. For the feeding tests,

proportional amounts based on the yield of each cutting were carefully blended to provide a uniform feed from each cutting interval.

For the digestion trials, wethers in a 4 × 4 Latin square design were used. Seven-day preliminary periods and seven-day collection periods were used. All chemical analyses were by A.O.A.C. methods (1955). Total digestible nutrients were calculated by the conventional method. The lignin analyses were made by the method of Ellis *et al.* (1946). True digestibility of protein was calculated by multiplying the factor of .02811 by the dry matter intake in grams to obtain the metabolic protein in the feces (Blaxter and Mitchell, 1948).

Effect of Stage of Maturity on Digestibility, Yield and Stand Survival. Cutting the alfalfa on a calendar basis as described above resulted in hay

TABLE 2. DESCRIPTION OF ALFALFA USED (SECOND CUTTING) IN THE 1955 DIGESTION TRIAL

Stage of maturity	Date cut	Days' growth	Height, in.
Pre-bud	5/8	18	15
1% bud	5/12	22	21
62% bud	5/16	26	26
11% bloom	5/21	31	35
46% bloom	5/26	36	38
96% bloom	6/3	43	42

of widely varying quality because the stage of maturity at cutting differed within the cutting intervals (table 1). Yield also dropped markedly as the season progressed, particularly with the shorter cutting intervals. Two additional studies were designed to study the effect on digestibility and yield when alfalfa was cut by stage of maturity. The first was to determine the effect of six stages of maturity on digestibility. The second was to study over a period of four years the effect of continued cutting of alfalfa at four stages of maturity on yield, chemical composition and stand survival.

For the digestibility studies another field of California Common alfalfa was selected. The entire field was mowed on April 20, 1955 to establish a uniform starting date. The forage for feeding was harvested on the dates and at the stages of maturity shown in table 2.

The material for each treatment was cut with a forage harvester and taken immediately to a commercial dehydrator, where it was dried and ground. The ground forage was then bagged and later pelleted into 3/8-inch pellets. For digestion trials, wethers in a 6 × 6 Latin square design were employed. Again, seven-day preliminary periods with seven-day collection periods were used. Total digestible nutrients were obtained by the digestible organic matter method of Lofgreen (1953).

For yield and stand survival studies a new seeding of Caliverde alfalfa was selected for a four-year trial on the effect of harvesting at pre-bud,

bud, 1/10 bloom and 1/2 bloom stages of maturity. Plots 20 × 30 ft. were replicated six times for each stage of maturity. Each spring the first cutting was taken from all plots at the same time without regard to stage of maturity. This removed the winter growth and provided a uniform starting date for all plots. Except in 1955 when the first cutting on the new stand was mainly weeds, yield and composition of this material were recorded, but as this forage was not of the same quality as that obtained by cutting at the specified stages of maturity, yield data are reported

TABLE 3. CUTTING DATES OF ALFALFA HARVESTED AT FOUR STAGES OF MATURITY

Cutting number	Stage of maturity			
	Pre-bud	Bud	1/10 bloom	1/2 bloom
1955				
1	May 26	May 26	May 26	May 26
2	June 16	June 22	June 29	July 6
3	July 8	July 18	July 29	Aug. 10
4	28	Aug. 12	Aug. 30	Sept. 20
5	Aug. 18	Sept. 9	Oct. 11	Oct. 11[a]
6	Sept. 9	Oct. 11		
7	Oct. 11			
1956				
1	Apr. 9	Apr. 9	Apr. 9	Apr. 9
2	May 16	May 22	June 1	June 8
3	June 8	June 18	29	July 13
4	29	July 13	July 30	Aug. 16
5	July 20	Aug. 6	Aug. 29	Sept. 21
6	Aug. 13	Sept. 4	Oct. 3	
7	Sept. 4	Oct. 5		
8	Oct. 9			
1957				
1	Mar. 25	Mar. 25	Mar. 25	Mar. 25
2	Apr. 22	Apr. 29	May 6	May 13
3	May 13	May 27	June 10	June 17
4	June 6	June 21	July 5	July 15
5	27	July 15	Aug. 6	Aug. 15
6	July 19	Aug. 9	Sept. 6	Sept. 20
7	Aug. 12	Sept. 3	Oct. 12	Oct. 17[b]
8	Sept. 3	Oct. 7		
9	Oct. 3			
1958	All cut at approximately 1/10 bloom			
1	Apr. 16	Apr. 16	Apr. 16	Apr. 16
2	May 26	May 26	May 26	May 26
3	June 26	June 26	June 26	June 26
4	July 25	July 25	July 25	July 25
5	Aug. 19	Aug. 19	Aug. 19	Aug. 19
6	Oct. 2	Oct. 2	Oct. 2	Oct. 2

[a] No bloom.
[b] Early bloom.

both with and without the first cutting for 1956 and 1957. Using the method described above for determining stages of maturity, each plot was harvested as it reached the appropriate stage. The dates and numbers of cuttings at each stage are shown in table 3. At cutting time green weight was obtained and a representative sample from each replication of the forage was taken for the determination of dry matter and protein. This treatment of all plots was continued for three years (1955, 1956 and 1957). To test the effect of this differential cutting on stand survival and plant vigor, all plots were harvested at the same stage of maturity (approximately 1/10 bloom) during the 1958 growing season.

Results

Cutting Interval Study (Calendar Basis—1954). Yield and composition of the alfalfa cut at 3-, 4-, 5- and 6-week intervals are shown in table 4.

TABLE 4. YIELD AND AVERAGE COMPOSITION OF ALFALFA PRODUCED BY CUTTING AT THREE-, FOUR-, FIVE- AND SIX-WEEK INTERVALS

No. of cuttings	Yield per acre, lb.		Composition, dry basis		
	Dry matter	Protein	Protein, %	Carotene, p.p.m.	Crude fiber, %
		Three-week cutting interval			
8	10,512	2,603	25.3	260	22.2
		Four-week cutting interval			
6	15,750	3,153	20.5	229	26.1
		Five-week cutting interval			
5	18,566	3,188	17.4	208	28.9
		Six-week cutting interval			
4	18,782	2,881	16.3	167	30.2

Harvesting at three-week intervals markedly reduced the yield of dry matter with a very sharp drop in production late in the season. Although protein and carotene in this harvested material were high, the protein yield was the lowest for this treatment. The four-week cutting interval also resulted in some reduction in yield late in the season but the effect was less marked than with the three-week interval. The dry matter yield per acre at the five-week interval approached that of the six-week interval and produced the highest yield of protein per acre. It should be noted that the growing period for the five-week interval was 25 weeks as compared to 24 for all other treatments.

The composition of the composite hay is shown in table 5. The decrease in lignin in the six-week cutting interval compared to the five-week cutting interval may be explained by larger amounts of recurrent growth in this

TABLE 5. COMPOSITION OF HAY FED IN 1954 DIGESTION TRIALS (DRY BASIS)

Cutting interval	Crude protein	Crude fiber	Lignin	Nitrogen-free extract	Ether extract	Ash	Carotene
	%	%	%	%	%	%	p.p.m.
3 weeks	27.8	21.8	7.1	37.8	1.4	11.2	17
4 weeks	22.1	27.2	8.0	38.9	1.2	10.6	14
5 weeks	18.2	31.1	9.5	40.3	1.0	9.4	19
6 weeks	17.6	31.1	9.3	41.0	1.3	9.0	12

sample. The recurrent or new growth was observed to be 6 to 8 inches in height at cutting time for the six-week interval.

The digestibility and total digestible nutrient content of the four types of hays are reported in table 6. The digestibility of the organic matter, protein and the nitrogen-free extract and the total digestible nutrient content decreased with each increase in the cutting interval. There was little if any difference in fiber digestibility at the four- and five-week cutting intervals, but the fiber of the six-week cutting interval was markedly less digestible than that from the three-week cutting interval. The true digestibility of the protein showed no difference.

The net result in terms of digestible protein and total digestible nutrient yield per acre for the season (less the first cutting) is given in table 7. The greatest yield of digestible protein came from the four-week cutting interval, while the largest yield of total digestible nutrients came from the five-week cutting interval. Unless high protein forage demands a particu-

TABLE 6. DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS OF ALFALFA CUT AT VARIOUS INTERVALS 1954

Cutting interval	Organic matter	Crude protein		Crude fiber	Nitrogen-free extract	Total digestible nutrients (dry basis)
		Apparent digestibility	True digestibility			
3 weeks	71.1	84.3	94.4	51.4	76.1	63.4
	(1.3)[a]	(.7)	(1.3)	(2.8)	(1.3)	(1.0)
4 weeks	65.6	81.3	94.0	45.5	73.4	58.9
	(1.9)	(.5)	(1.1)	(3.7)	(2.0)	(1.0)
5 weeks	64.0	78.3	93.9	48.0	72.0	58.1
	(1.0)	(.5)	(.9)	(2.0)	(2.0)	(1.0)
6 weeks	61.0	76.4	92.3	40.7	71.8	55.6
	(2.3)	(1.9)	(3.0)	(4.7)	(2.0)	(2.0)
LSD (.05)	3.1	1.5	N.S.	6.0	2.0	2.1
(.01)	4.7	2.3	....	9.1	3.0	3.2

[a] Standard deviation.

TABLE 7. YIELD OF DIGESTIBLE PROTEIN AND TOTAL DIGESTIBLE NUTRIENTS PER ACRE 1954

Cutting interval	Digestible protein, lb.	Total digestible nutrients, lb.
3 weeks	2,194	6,665
4 weeks	2,563	9,277
5 weeks	2,496	10,787
6 weeks	2,201	10,443

lar premium, it appears that under the conditions of this experiment the five-week interval would be the most economical basis to use in planning a cutting interval.

The effect of the varying cutting intervals on plant vigor is shown in the root and crown size, in the dry matter production and in the ability of stands to compete with weeds (figure 2). The root and crown weights, expressed as percentage of plants by treatments in December, 1954, following the cutting interval program, were in the order of 100% for the 42-day interval, 82% for the 35-, 62% for the 28-, and 45% for the 21-day cutting interval. The dry matter yield for the first cutting in 1955 for the six-week interval plots was 3,000 lb.; the five, 2,760; the four, 2,220; and for the three-week interval plots, 2,100 lb. per acre. Weeds accounted for 1.0% of the yield of the 35- and 42-day cutting interval, while 23% and 36% of the yield of the 28- and 21-day interval, respectively, consisted of weeds.

Cutting Interval Based on Stage of Maturity (1955)—Digestibility Study. The composition and yield of alfalfa cut according to stage of

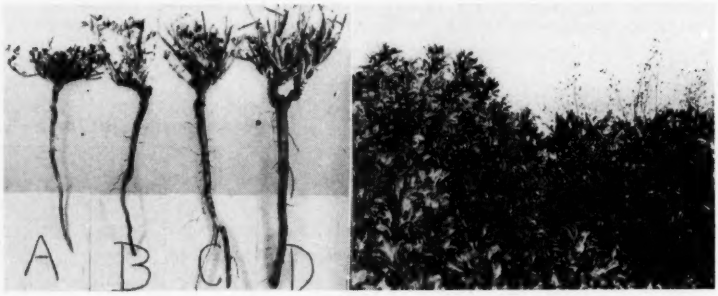

Figure 2.

Left: Crown and tap root following various cutting intervals, A—3-week; B—4-week; C—5-week; D—6-week.

Right: Adjoining plots first cutting alfalfa in the spring of 1955. At left, plot cut at 6-week interval; at right, plot cut at 3-week interval during 1954 growing season.

TABLE 8. COMPOSITION OF ALFALFA CUT ACCORDING TO STAGE OR MATURITY SECOND CUTTING (1955)

Vegetative stage	Composition, dry basis		
	Protein	Crude fiber	Lignin
	%	%	%
Pre-bud	30.9	15.2	5.3
1% bud	26.9	20.9	6.4
62% bud	25.2	21.7	6.6
11% bloom	21.3	27.3	8.2
46% bloom	19.1	28.5	8.2
96% bloom	16.9	31.4	8.3

maturity are shown in table 8. The pre-bud stage produced high-protein and low-fiber hay, the protein decreasing and the fiber and lignin increasing as the plants matured.

The digestion coefficients for organic matter, protein, the true digestibility of the protein (corrected for metabolic protein in the feces) and the total digestible nutrients of the alfalfa cut at the six stages are given in table 9. The digestibility of the organic matter decreased rapidly until the 11% bloom stage and then leveled out. The apparent digestibility of

TABLE 9. PROTEIN DIGESTIBILITY AND TOTAL DIGESTIBLE NUTRIENTS OF SECOND CUTTING ALFALFA HARVESTED AT SIX STAGES OF MATURITY—1955

Vegetative stage	Organic matter digestion coefficient	Crude protein		Total digestible nutrients (dry basis)
		Apparent digestion coefficient	True digestion coefficient	
Pre-bud	73.1	78.8	87.9	66.1
	(2.4)[a]	(2.0)	(2.0)	(2.4)
1% bud	68.7	75.8	85.9	61.9
	(1.7)	(1.0)	(.8)	(1.8)
62% bud	64.2	73.4	84.4	58.9
	(5.1)	(3.4)	(3.4)	(5.1)
11% bloom	61.9	72.8	85.4	57.2
	(3.8)	(2.7)	(2.7)	(3.9)
46% bloom	60.1	70.3	84.8	54.7
	(2.7)	(2.2)	(2.2)	(2.7)
96% bloom	60.2	69.2	84.4	55.7
	(3.8)	(3.0)	(3.0)	(3.9)
LSD (.05)	3.3	3.2	N.S.	3.0
(.01)	4.5	4.3	....	4.1

[a] Standard deviation.

the protein decreased from pre-bud to 62% bud and then leveled out. As in the previous year's results there was no difference in true digestibility of protein. The TDN was significantly lower in the bud stage than in the pre-bud stage with no significant difference in the bloom stages.

TABLE 10. YIELD OF ALFALFA CUT AT FOUR STAGES OF MATURITY FOR THREE GROWING SEASONS

Stage of maturity and year	No. of cuttings	Seasonal yield, lb. per acre		Protein yield, lb. per acre	
		Including 1st cutting	Without 1st cuttings (1956 and 1957)	Including 1st cutting	Without 1st cuttings (1956 and 1957)
1955					
Pre-bud	6	11,289	11,289	2,918	2,918
Bud	5	12,988	12,988	3,086	3,086
1/10-bloom	4	14,716	14,716	2,948	2,948
1/2-bloom	4	14,796	14,796	2,795	2,795
1956					
Pre-bud	8	17,373	12,277	4,291	3,347
Bud	7	19,892	15,130	4,436	3,543
1/10-bloom	6	22,731	17,881	4,755	3,645
1/2-bloom	5	21,867	16,785	4,240	3,107
1957					
Pre-bud	9	14,796	11,921	3,964	3,216
Bud	8	18,920	15,863	4,654	3,833
1/10-bloom	7	21,686	18,593	4,806	3,971
1/2-bloom	7	23,551	19,950	4,795	3,873
Total for 3 years					
Pre-bud	23	43,458	35,487	11,173	9,481
Bud	20	51,800	43,981	12,176	10,462
1/10-bloom	17	59,133	51,190	12,509	10,564
1/2-bloom	16	60,214	51,531	11,830	9,775
LSD	.05	3,652	3,710	806	711
	.01	4,458	9,953	1,127	869

Four-year Study on Yield, Composition and Stand Vigor. The seasonal yield of dry hay and protein produced during the three seasons when the plots were cut at the assigned stages of maturity is shown in table 10. All cuttings were made according to plan except that the last cutting to be cut at the half-bloom stage failed to flower in October, so it was harvested without proper flowering in 1955 and 1957. The data showing all cuttings give the total forage produced from May 26, 1955 to early October 1957. The next column which omits the first cutting in 1956 and 1957 represents the total forage cut at the specified stages of maturity.

Analysis of variance on the yield data for the total dry matter for the three seasons showed highly significant differences for treatment and replications. Analysis of variance by season showed highly significant treatment and season effects with a highly significant interaction for season by treatment. When the interaction value was used as the denominator, treatment was highly significant both with and without the first cuttings included; season was highly significant with the first cuttings included but significant ($P<.05$) without the first cuttings included. Clearly, the alfalfa cut at the bloom stages produced more dry matter than that cut at the bud stage, and that cut at the pre-bud stage produced the least. Analysis of the protein yield data showed highly significant differences by treatments on the three-year total. When analyzed by season, highly significant values were obtained for treatment, season, replications and treatment x season interaction. When tested with the interaction value as denominator, only season was significant. The alfalfa cut at 1/10-bloom produced the most protein after the first season and that cut in the bud stage produced well in the first season but less in the second and third seasons. The pre-bud cut alfalfa produced almost as much as that cut at 1/10-bloom in the first season but dropped to the lowest protein production by the third season.

TABLE 11. YIELD OF ALFALFA DURING FOURTH SEASON AFTER BEING CUT AT FOUR STAGES OF MATURITY THE THREE PREVIOUS SEASONS

Previous treatment	No. of cuttings	Seasonal yield, lb. per acre	Protein yield, lb. per acre
Pre-bud	6	17,380	3,884
Bud	6	17,860	3,993
1/10-bloom	6	18,237	3,978
1/2-bloom	6	18,361	4,015
		N.S.	N.S.

The yield during the fourth season when all the alfalfa was cut at approximately 1/10 bloom is shown in table 11. Although the data appear to show a slight trend toward the plots cut previously at the more mature stages, analysis of variance showed the differences to be non-significant; that is, despite three seasons of differential cutting, the alfalfa produced at the same rate during the fourth season when all plots were cut at the same time. Stand counts made during the four years of this study showed no difference in plant density due to cutting treatments. The reduced yield of the more frequently cut plots resulted from fewer culms per plant and slower recovery after cutting.

Table 12 shows the average seasonal yield for the three years. To calculate the production of total digestible nutrients and digestible protein per acre, the digestibility data obtained earlier (table 9) for the various

stages of maturity were used as the best available estimate. When the total yield is multiplied by the TDN content per pound, the greatest production of TDN is clearly by the alfalfa cut at the 1/10 bloom stage of maturity. The slightly greater dry matter yield of the 1/2 bloom alfalfa is more than offset by the reduced digestibility. The largest production of digestible protein came from the alfalfa cut at bud stage, followed closely by that cut at 1/10 bloom. With the pre-bud stage material, the high digestion coefficient could not overcome the low production, and with the 1/2 bloom hay the lower digestibility of the protein further depressed the amount of digestible protein available.

TABLE 12. CALCULATED YIELD OF TOTAL DIGESTIBLE NUTRIENTS AND DIGESTIBLE PROTEIN FROM ALFALFA CUT AT FOUR STAGES OF MATURITY

Stage of maturity	Pre-bud	Bud	1/10-bloom	1/2-bloom
Average seasonal yield, lb. per acre[a]	11,829	14,660	17,063	17,177
TDN per lb.	0.661	0.604[b]	0.572	0.547
TDN yield, lb. per acre	7,819	8,855	9,760	9,396
Average protein yield, lb. per acre	3,160	3,487	3,521	3,258
Protein digestion coefficient	78.8	74.6[b]	72.8	70.3
Digestible protein, lb. per acre	2,490	2,601	2,563	2,290

[a] Without the first cutting 1956 and 1957.
[b] Average of values for 1% bud and 62% bud.

Discussion

Although the results reported here are most applicable to irrigated alfalfa produced in an area with a long growing season, they demonstrate further the desirability of harvesting forage before it is so mature that decreased digestibility offsets the increased dry matter obtained as the forage matures. At the other extreme, forage cut at too immature stages, while highly digestible, will not continue to yield enough total forage to make the production of this product practical. The increased number of haying operations per season, coupled with the greater difficulty in drying the immature forage, further increase the cost and labor involved with the short cutting interval. The hay producer interested only in total hay yield will usually cut at the more mature stages—1/2 bloom or later—because he knows from experience that his total yield is high and the hay is easily cured. To produce the maximum feed value as indicated by TDN and digestible protein per acre, the hay should be cut in the late bud to early bloom stages. If hay purchasers buy on the basis of protein analyses or preferably lignin or crude fiber content as suggested by Meyer *et al.* (1959), hay producers will become more conscious of producing a quality product by harvesting at earlier stages of maturity.

For hay production where the hay can be cut at a definite stage of maturity, the studies reported here show that alfalfa cut when 10% of the stems have one or more flowers in bloom will produce the largest tonnage of TDN and a good yield of digestible protein without seriously affecting the vigor of the stand. Woodman and Evans (1935) have reported the starch equivalent content and yield of alfalfa. By calculation their data show a yield of starch equivalent of 2,210 lb. for five cuttings at the pre-bud stage, 3,282 lb. for three cuttings at the bud stage and 3,209 lb. for three cuttings at the early flower stage.

In planning a soilage operation or pasture rotation where a definite time schedule is essential, considering yield of TDN and digestible protein and vigor of the alfalfa plants, a cutting every four to five weeks was best under the conditions of these trials. The digestibility results on this trial confirm the results of Woodman *et al.* (1933) who showed that the digestibility of alfalfa was lower at the flower stage than at the bud stage of development and that the digestibility of grass pasture declined as the pasture was cut at three-, four- and five-week intervals.

In both digestion trials the apparent digestibility of protein decreased with the increasing maturity of the alfalfa. However, when the true digestibility was calculated by the method of Blaxter and Mitchell (1948) no differences remained (tables 6 and 9). This reflects the diluting effect of the increased fiber or bulk of the more mature forages. The higher amount of metabolic protein in the feces is a direct result of the increased bulk. The higher percentages of fiber and the lower percentage of protein in the more mature roughage are both reflected in the differences found in the apparent digestion coefficients. From the practical viewpoint, however, the digestible protein, as computed from the apparent digestibility, is the protein which is available to the animal for meeting his needs. For this reason, the digestible protein yield per acre (tables 7 and 12) is based on the apparent digestibility coefficients for protein.

The depletion of plant reserves and reduced plant vigor as a result of too frequent cuttings were clearly demonstrated by reduced root and crown size, weed invasion and reduced first crop production in the first study. In the four-year study when the forage was cut by stage of maturity during the first three years the production of pre-bud and bud stage plots did not produce as well, compared to the 1/2 bloom plots, in the third year as in the first year. In protein yield per acre, the pre-bud cut plots produced well the first year but by the third season they yielded the lowest amount by quite a margin. In the fourth year of this test, however, there was no significant difference in yield when all plots were cut at the same stage of maturity. This demonstrates the ability of the alfalfa plant to recover under good conditions. Plant density counts made annually during the course of this trial indicated that the various cutting

treatments had not decreased the stand density. Irrigation of all plots had been based on the needs of the pre-bud plots as they were consistently the plots first to indicate a need for water.

Summary

Chemical composition, digestibility by sheep, and yield of digestible protein and total digestible nutrients per acre were obtained by a series of studies on irrigated alfalfa. In the first study, alfalfa was cut at 21-, 28-, 35- and 42-day intervals for 24 and 25 weeks after the removal of the first cutting. The largest amount of digestible protein was produced by the four-week cutting interval and the most total digestible nutrients by the five-week cutting interval. Plant vigor, as measured by crown and root weights and production and weediness of the first crop the following year, was reduced by the three- and four-week cutting intervals. In the second study, second cutting alfalfa from a different field was harvested by stage of maturity at pre-bud, 1% bud, 62% bud, 11% bloom, 46% bloom and 96% bloom. Digestibility data were obtained for each stage of maturity. To study the yield of alfalfa cut by stage of maturity, a trial was conducted for 4 years in which alfalfa was cut at the pre-bud, bud, 1/10 bloom and 1/2 bloom stage for 3 years and then all plots cut at the same stage in the fourth year to measure the after effects of the three previous year's treatment. During the 3 years of differential treatment, the greatest dry matter yield was produced by the alfalfa cut at the bloom stages. The greatest protein yield was by that cut at the 1/10 bloom stage. In the fourth season when all alfalfa was cut at the same stage, there was no significant difference in yield despite the difference in treatment during the previous three seasons.

When the average annual yield during the three seasons of cutting by stage of maturity is multiplied by the digestibility results from the digestion trial on alfalfa cut by stage of maturity, the largest yield of total digestible nutrients came from the alfalfa cut at the 1/10 bloom stage and the largest yield of digestible protein from the alfalfa cut at the bud stage.

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A PHOTOELECTRIC METHOD FOR ESTIMATING THE CONCENTRATION OF SPERM IN BOAR SEMEN [1]

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THE growing interest in artificial insemination of swine, has emphasized the need for rapid methods of estimating the quality of boar semen (Polge, 1956), particularly with respect to its sperm concentration. Since the time that Comstock and Green (1939) developed the photoelectric method for estimating sperm concentration in ram semen, this method has been further refined by Emik and Sidwell (1947) for ram semen, and adapted for use to bull semen by Salisbury *et al.* (1943). Although the method has generally replaced the slower one of counting sperm with a hemocytometer, as used by Milovanov (1937), the authors have found no reports in the literature in which the method has been used for adapting the photoelectric procedure for estimating sperm concentration in boar semen.

Experimental Procedure

Although Willett and Buchner (1951) and Emik and Sidwell (1947) found that dilution rate was not an important source of error in estimating sperm counts in bull and ram semen, and Salisbury *et al.* (1943) and Emik and Sidwell (1947) found that sub-sampling ejaculates contributed very little error in estimating sperm concentration in bull semen, it was thought that sampling of boar semen still might be an important cause of variation in sperm counts in this species because boars produce a larger ejaculate of semen than other farm animals, and the turbidity of the nonsperm elements in boar semen is relatively high (Polge, 1956). Also, since Foote (1951) has shown that refrigeration and careful remixing of bull semen are required to prevent changes in estimated sperm counts within 24 hours after collection, it was thought that delay in determining the sperm concentration of boar semen might cause considerable variation in the estimates due to difficulty in thoroughly remixing the sample and/or an increase in turbidity due to bacterial growth. Therefore, the following sources of variability were included in these studies: (1) dilution rate of the semen, (2) procedures for sampling and sub-sampling the ejaculates,

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and (3) the interval of time between ejaculation and the estimation of the sperm concentration.

For these studies a total of 25 ejaculates of semen were obtained from one Yorkshire and three Chester White boars each ejaculated once a week. The semen was strained through a single layer of cheesecloth to remove the gelatinous material and then mixed in a graduated glass-stoppered cylinder by inverting three or four times.

Samples of approximately 18 ml. each were taken with a pipette immediately after mixing the ejaculate, one from the top and one from the bottom of the cylinder, and placed in 20-ml. tubes, corked, and stored at 5° C. Eighteen-ml. samples in the 20-ml. tubes were used to minimize evaporation and at the same time provide for easy remixing of the samples. Sub-samples, one for the Photelometer transmittancy measurements and one for hemocytometer counts, were removed on the day of collection and the following day. Just before removing each day's sub-samples the tubes of semen were inverted ten times.

Hemocytometer counts were made on the undiluted semen by withdrawing the semen from the sample tube with a white-blood-cell pipette and diluting 1:33 in the pipette with a 2% solution of acetic acid. After shaking each white-cell pipette containing the diluted semen with a pipette shaker for about 2 minutes enough fluid was blown out of the pipette to insure that well-mixed semen was at the tip of the pipette. The counting chamber of the hemocytometer then was filled, care being taken not to overflow it. The sperm were allowed to settle for 3 to 5 minutes and then counted. Five large squares of the counting chamber, starting with the upper left square and counting diagonally down to the lower right, were counted as described by Bratton *et al.* (1956) and by Turkheimer (1956). Only single hemocytometer counts were made on each sub-sample, since Turkheimer (1956) obtained a correlation of 0.99 between duplicate counts on the same sub-samples.

A Cenco-Sheard-Sanford Photelometer connected to a constant-voltage transformer was used to determine the light transmittancy of the diluted semen in tubular absorption cells, using the green filter with maximum transmission at 530 mμ. The standard reference tube contained 4 ml. of 2.9% sodium citrate dihydrate. Operational instructions supplied by the manufacturer were followed carefully.[3]

In a preliminary experiment using 12 ejaculates, samples of which were diluted at rates of 1:4, 1:9, 1:19, and 1:39, it was found that the rates of 1:9 and 1:19 gave Photelometer readings the majority of which were within the most sensitive range of this type of instrument, namely 30% to 70% transmittancy.

The 1:9 dilution rate was obtained by pipetting 3.6 ml. of a 2.9% sodium citrate dihydrate solution into a clean absorption cell and adding

[3] Central Scientific Company, 1949.

0.4 ml. of semen with another pipette. The 1:19 dilution rate was obtained by using 3.8 ml. of the citrate solution and 0.2 ml. of semen. After adding the semen to the citrate solution, part of the solution was drawn back into the pipette three times to rinse the pipette.

The absorption cells were tightly corked, their contents thoroughly mixed by vigorous shaking for approximately 10 seconds and the light transmittancy measured promptly. Repeated readings were obtained on each absorption cell and its contents until two identical readings were obtained. Between each reading, the Photelometer was checked against the standard reference cell for 100% transmittance. In general, three readings were sufficient to obtain two that were identical.

The sperm number equivalents of the transmittancy measurements were based upon hemocytometer counts of sperm numbers in the diluted semen of the absorption cells used for the transmittancy measurements. The two dilution rates, 1:9 and 1:19, being further diluted to 1:33 by adding 7.2 ml. of a 2.83% acetic acid solution to 3 ml. of the contents of the absorption cells of the 1:9 dilution, and 2.11 ml. of a 4.86% acetic acid solution to 3 ml. of the 1:19 dilution. The final concentration of acetic acid in these 1:33 dilutions was 2%, the same as was used for the counts on the raw semen.

Results and Discussion

Table 1 is a summary of the photometric transmittancy values for the dilution rates of 1:4, 1:9, 1:19, and 1:39 in the preliminary experiment.

Table 2 shows the summary of averages and ranges in transmittancy values for the two time intervals, day 0 and day 1, the two positions sampled, top and bottom, the two dilution rates, 1:9 and 1:19, and the hemocytometer counts for the undiluted semen and the diluted semen on which the transmittancy values were obtained. From a component of variance analysis it was found that ejaculates contributed 26% and dilution rates 54% of the total variance. Thus the procedure for subsampling the ejaculate, the time lapse in making counts, and other unknown factors contributed only 20% of the total variance.

TABLE 1. TRANSMITTANCY VALUES IN THE PRELIMINARY EXPERIMENT

Number of samples	Dilution rate of semen	Averages and standard deviations of transmittancy values	Range of transmittancy values
12	1:4	17± 4	7–27
12	1:9	32± 8	16–43
12	1:19	54±10	34–67
12	1:39	73± 8	60–84

TABLE 2. MEANS AND RANGES OF TRANSMITTANCY VALUES AND HEMOCYTOMETER COUNTS OBTAINED FOR DIFFERENT COMBINATIONS OF SUB-SAMPLES (25 EJAC.)

Instrument used	Sub-sample: Day	Sub-sample: Location	Final dilution rate	Mean	Range
				(Percent transmittancy)	
Photelometer	0	Top	1:9	40	12–79
"	0	Bottom	1:9	40	17–79
"	1	Top	1:9	38	14–69
"	1	Bottom	1:9	38	14–69
"	0	Top	1:19	61	30–93
"	0	Bottom	1:19	62	30–94
"	1	Top	1:19	59	32–85
"	1	Bottom	1:19	59	32–83
Hemocytometer—				(Sperm	
Raw undiluted semen				no. x 10^6 per ml.)	
"	0	Top	1:33	287	43–823
"	0	Bottom	1:33	298	48–845
"	1	Top	1:33	286	63–739
"	1	Bottom	1:33	287	61–772
Diluted semen from absorption cells					
"	0	Top, 1:9	1:33	300	53–749
"	0	Bottom, 1:9	1:33	300	56–789
"	1	Top, 1:9	1:33	304	73–815
"	1	Bottom, 1:9	1:33	300	46–733
"	0	Top, 1:19	1:33	280	58–780
"	0	Bottom, 1:19	1:33	273	41–663
"	1	Top, 1:19	1:33	276	61–568
"	1	Bottom, 1:19	1:33	283	63–739

The extremely high correlations between the transmittancy values for the positions sampled, the dilution rates, and the day sub-sampled are shown in table 3.

The correlations between hemocytometer counts and the transmittancy

TABLE 3. CORRELATIONS BETWEEN TRANSMITTANCY VALUES

Number of ejaculates	Transmittancy values correlated: Sub-sample and day	Transmittancy values correlated: Sub-sample and day	Correlation coefficient
45	Top 1:9 0	Bottom 1:9 0	0.996
45	Top 1:19 0	Bottom 1:19 0	0.992
25	Top 1:9 0	Top 1:9 1	0.974
25	Top 1:19 0	Top 1:19 1	0.959
25	Top 1:9 1	Bottom 1:9 1	0.997
25	Top 1:19 1	Bottom 1:19 1	0.994

TABLE 4. CORRELATIONS BETWEEN HEMOCYTOMETER COUNTS AND TRANSMITTANCY VALUES EXPRESSED AS 2 — LOG OF THE TRANSMITTANCY VALUES

Sub-samples used for hemocytometer counts[a]		Sub-samples used for transmittancy measurments			Correlation coefficient
Location	Days stored	Dilution	Location	Days stored	
Top	0	1:9	Top	0	0.96
Bottom	0	1:9	Bottom	0	0.96
Top	1	1:9	Top	1	0.95
Bottom	1	1:9	Bottom	1	0.96
Taken from the same absorption cells used in the photoelectric determination but further diluted to the final rate of 1:33		1:9	Top	0	0.97
		1:9	Bottom	0	0.96
		1:9	Top	1	0.95
		1:9	Bottom	1	0.96
		1:19	Top	0	0.93
		1:19	Bottom	0	0.95
		1:19	Top	1	0.91
		1:19	Bottom	1	0.95

[a] The first four hemocytometer counts were made directly from the sub-sample and diluted 1:33.

values, expressed as 2 — log of the values, are shown in table 4. These correlations were unexpectedly high, in view of the rather turbid nature of the nonsperm fraction of boar semen. Nevertheless, it is concluded from these high correlations that this simple photometric procedure is quite satisfactory for estimating the concentration of sperm in boar semen.

The regression equations for estimating number of sperm in millions per ml. of semen ($\hat{Y}$) at the 1:9 and 1:19 dilution rates and using top

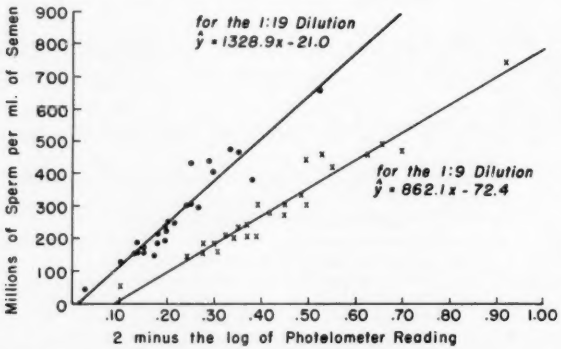

Figure 1. The regression of hemocytometer counts of sperm numbers x 10^6 per ml. of semen on 2 — log of the Photelometer reading when semen was diluted 1:9 and 1:19.

sub-samples on day 0, when X equals 2 — log of the Photelometer readings (% transmittancy), are shown in figure 1.

From these regression equations tables were constructed showing the estimated sperm counts for semen dilution rates of 1:9 and 1:19 for all readings on the scale of the Photelometer. As with ram and bull semen this photometric procedure saves considerable time in evaluating boar semen.

Summary

The turbidometric method for estimating sperm concentration in ram and bull semen was adapted to boar semen using a Cenco-Sheard-Sanford Photelometer. Correlations of 0.95 or higher were obtained between hemocytometer counts of sperm concentration and Photelometer readings expressed as 2 — log of the Photelometer reading. Semen dilution rates of 1:9 and 1:19 gave readings, most of which were within the more sensitive range on the Photelometer scale. No significant differences were found between the average sperm counts made by the hemocytometer, or between transmittancy values of samples taken from the top and the bottom of the ejaculate on day 0 and day 1. The regression equations for estimating sperm concentration ($\hat{Y}$) in millions per ml. in boar semen were, for the 1:9 dilution rate, $\hat{Y}=862.1X-72.4$, and for the 1:19 dilution rate, $\hat{Y}=1328.9X-21.0$, where X equals 2 — log of the Photelometer reading. As with ram and bull semen this photelometric procedure saves considerable time in evaluating boar semen.

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CHLORPROMAZINE RESIDUES IN BEEF TISSUES [1, 2, 3]

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DRUGS producing artificial sedation are not new, neither are tranquilizing agents wholly novel, but their relationships to large animals have recently excited the imagination of research workers. Many uses are being proposed for tranquilizers in farm animals. These drugs seem to have various properties which are useful in the feeding, handling, and transporting of livestock.

Chlorpromazine hydrochloride is a synthetic water-soluble derivative of phenothiazine. Like many tranquilizers, chlorpromazine has been credited with antemetic, central nervous system depressing and other properties which aid animals in ignoring noxious stimuli. One useful property of this compound is its ability to relieve physiological stress. This, combined with the ability to produce sedation without harmful side effects, has encouraged experimentation in livestock feeding and handling prior to slaughter. The dosage and the effect of the agent on the carcass is a matter of great concern to the livestock and meat industry. The purpose of this study was to determine the residual effect of chlorpromazine in the tissues when injected into the beef animal.

Materials and Methods

Animals from the Oklahoma Agricultural Experiment Station herd were used in this study. A Shorthorn cow and three Angus heifers were used to determine dosage for sedation. Six Hereford calves, weighing 350 to 400 lb., were slaughtered after treatment to provide tissues for assay.

The chlorpromazine hydrochloride was injected intravenously (I.V.) at various levels and at various periods prior to slaughter. Injections were made into the jugular vein. Intramuscular injections (I.M.) were placed in the approximate area of the *infraspinatus* muscle. Both sides of the animal were used when intramuscular injections were made over extended periods prior to slaughter. Slaughtering was done according to experimental procedure reported by Deans (1951).

Tissue samples were collected, wrapped and frozen immediately following dressing and after varied periods of chilling at 36° F. All samples were frozen at 0° F. and stored at this temperature until removed for assay.

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[2] Journal Series Paper No. 417, approved by the Director of the Oklahoma Agricultural Experiment Station.

[3] Financed in part by a Grant from the Smith, Kline, and French Labs., Philadelphia, Pa.

The methods of Salzman and Brodie (1956) were employed for the determination of chlorpromazine hydrochloride and chlorpromazine sulfoxide. A modification of this method by Flanagan and Novick (1958) was used to differentiate the free and bound form of the drug in the lean and fat. This method uses a multiple diethyl ether extraction of a basic tissue homogenate for the "free" form of the compound. The "bound" form was released by a sodium hydroxide digestion of the same aliquot of tissue homogenate. This hydrolyzed tissue aliquot was carried through the same extraction procedure as was used in the determination of the free chlorpromazine hydrochloride. The absorption spectra were determined on an acid extract of the combined diethyl ether phase, for both the free and the bound form. These curves when compared to a standard curve for chlorpromazine hydrochloride or chlorpromazine sulfoxide were used to calculate the concentration in the tissues.

Results and Discussion

One of the first questions that required investigation was that of dosage. In a trial and error study, it was revealed that the dosage for tranquilization varied considerably with the nature of the animal. For example, Angus heifers which were halter broken and not easily excited required a smaller dose to show visual tranquilization than animals from the range. One theory proposed for this was that animals from the range were physiologically prepared to meet an emergency situation. This suggested that the flow of adrenalin was more readily stimulated in this type of animal.

Dose levels of chlorpromazine hydrochloride administered intravenously at the rate of 0.25 mg./lb. body wt., to halter broken Angus heifers was sufficient to make them docile. These animals became docile in 2 to 3 minutes after injection. The heifers were led and handled easily. When they were left to stand without being disturbed, their eyes showed evidence of drowsiness, and the head appeared to be heavy. However, the animals had no great difficulty in walking. The extent and period of tranquilization was difficult to measure by an objective means. The visible effects of the drug appeared to have worn off in 2½ hours.

Intravenous dosage of 0.4 mg./lb. body weight was required for aggressive range Hereford beef calves. These calves varied in weight from 350 to 400 lb. Range stock required a larger dose to produce the required degree of tranquilization than more gentle stock. A dose of 0.8 mg./lb. body weight was not sufficient to sedate satisfactorily one range calf. This animal was visibly tranquilized, but responded to noxious stimuli by showing signs of alertness and fright.

When a dose of 0.8 mg./lb. was administered I.V. followed by multiple I.M. injections totaling 8 mg./lb. body weight, the period of tranquilization was extended. However, wild range calves were still quite alert and

TABLE 1. CHLORPROMAZINE HYDROCHLORIDE AND CHLORPROMAZINE SULFOXIDE CONTENT OF URINE [a]

Time after injection, hours	Urine volume, ml.	Method of obtaining urine	Chlorpromazine hydrochloride, mcg./ml.	Chlorpromazine sulfoxide, mcg./ml.
0	100	Bladder emptied	0.00	0.00
1	1000	Urination	0.29	1.51
2	750	Bladder emptied	0.01	1.48
3	1100	Urination	0.31	2.26
5	955	Bladder emptied	0.31	2.26
10	1870	Bladder emptied	0.72	4.34

[a] An 845-lb. Shorthorn cow received 0.19 mg./lb. of chlorpromazine hydrochloride by intravenous injection.

susceptible to fright when given 0.8 mg./lb. body weight. A dose of 0.18 mg./lb. body weight, when given by the I.V. route, was not adequate to sedate an 845-lb. Shorthorn cow. Some evidence of tranquilization was observed, but the condition remained for only a brief period.

Although chlorpromazine hydrochloride was effective in sedation of the beef animal, the drug caused some undesirable side effects. Hemoglobin was detected in the urine when chlorpromazine hydrochloride was administered by either the I.V. or I.M. route. When an Angus heifer was injected I.V. with 0.25 mg./lb. body weight of chlorpromazine, hemoglobin was detected in the urine within 2 hours after injection. The hemoglobin concentration diminished in subsequent urine samples and was not present after 24 hours. When 0.8 mg./lb. body weight were given I.V. over 2½ hour period, the urine was coffee colored. The research literature makes no reference to hemolysis in other animal species following treatment with chlorpromazine hydrochloride. Whether this effect is specific for the bovine has not been determined. Since the solution of chlorproma-

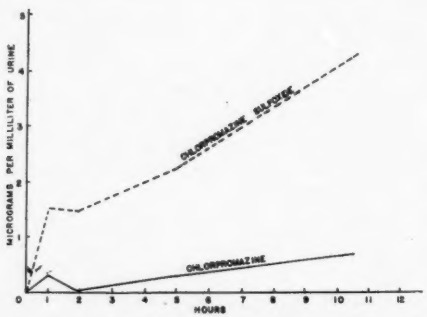

Figure 1. Chlorpromazine hydrochloride and chlorpromazine sulfoxide levels in bovine urine.

zine hydrochloride has a pH of 4.5 and fairly large doses were given intravenously, it may have caused a transient hemolysis at the time of injection. This condition would rapidly be abolished by the dilution of total blood volume, and may be the cause of the transient hemoglobinuria. Further work will be required to explain more completely the cause of the hemoglobinuria.

Extensive tissue damage was noted in slaughter animals at the site of intramuscular injections of the drug. The tissues were irritated and showed signs of inflammatory reaction. The extent of the damaged area surrounding the injection site was determined by the size of the dose. Part of the reason for the tissue damage can be attributed to the low pH level of the drug in solution.

TABLE 2. CHLORPROMAZINE HYDROCHLORIDE AND CHLORPROMAZINE SULFOXIDE CONTENT OF THE URINE [a]

Time after injection, hours	Urine volume, ml.	Presence of hemoglobin in the urine	Chlorpromazine hydrochloride, mcg./ml.	Chlorpromazine sulfoxide, mcg./ml.
0.0	75	No	0.00	0.00
2.5	1168	Yes	0.53	2.30
4.5	755	Yes	0.64	8.92
8.0	275	Yes	5.27	11.73
12.0	400	Yes	2.97	8.92
24.0	300	No	0.25	3.80

[a] An Angus heifer received 0.25 mg./lb. body weight of chlorpromazine hydrochloride by intravenous injection.

The amount of chlorpromazine lost through the bovine kidney was determined by utilizing two animals. The results of this work indicated that some of the compound was excreted in the urine as chlorpromazine hydrochloride or as a metabolite, chlorpromazine sulfoxide, during a 24-hour period (table 1). During the first 10-hour period, as shown in figure 1, a Shorthorn cow excreted 11.8% of the injected dose (0.19 mg./lb.) of chlorpromazine. In a subsequent trial, using an Angus heifer (table 2) where chlorpromazine hydrochloride was injected intravenously at a level of 0.25 mg./lb., 12.4% of the injected drug was accounted for in the urine during a 24-hour period. The levels of chlorpromazine hydrochloride and chlorpromazine sulfoxide rose sharply during the first 8 hours as shown in figure 2. A sharp drop was noted between 8 and 12 hours following injection. The drug and its metabolite levels in the urine both tended to fall slowly throughout the last 12-hour period.

Since only a small portion of the injected drug was accounted for by loss through the kidney, it was necessary to determine what proportion was being held or trapped in the edible tissues. This necessitated the injection of several animals with a constant dosage of 0.4 mg./lb. body

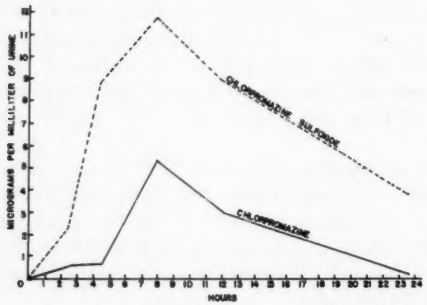

Figure 2. Chlorpromazine hydrochloride and chlorpromazine sulfoxide levels in bovine urine.

weight with varied intervals between injection and slaughter. Results of the chemical assays on nine tissues and blood are shown in table 3.

The only detectable chlorpromazine found after 4 hours was in the internal fat. In the animal slaughtered 8 hours after injection, small amounts of chlorpromazine residues were found in the heart, lung, brain and tongue. Chlorpromazine sulfoxide was detected in the kidney of the animal treated 8 hours before slaughter. Neither chlorpromazine hydrochloride nor chlorpromazine sulfoxide was detected in any of the tissues when the animal was slaughtered 72 hours after the intravenous injection.

TABLE 3. RESIDUAL CHLORPROMAZINE HYDROCHLORIDE AND CHLORPROMAZINE SULFOXIDE IN BEEF TISSUES

	Time from injection to slaughter			
	4 hours[a]		8 hours[a]	
Tissue	Chlorpromazine[b] hydrochloride, mg./100 gm.	Chlorpromazine sulfoxide,[c] mg./100 gm.	Chlorpromazine[b] hydrochloride, mg./100 gm.	Chlorpromazine sulfoxide,[c] mg./100 gm.
Muscle	0.01	0.03	0.01	0.03
Fat (internal)	0.09	0.03	0.01	0.03
Liver	0.01	0.03	0.01	0.03
Heart	0.01	0.03	0.09	0.03
Lung	0.01	0.03	0.10	0.03
Brain	0.01	0.03	0.05	0.03
Kidney	0.01	0.03	0.01	0.08
Tongue	0.01	0.03	0.06	0.03
Spleen	0.01	0.03	....	....
Blood	0.01	0.03	0.01	0.03

[a] Chlorpromazine Hydrochloride injected intravenously at a dose level of 0.4 mg./lb. body weight.
[b] Sensitivity to 0.01 mg./100 gm.
[c] Sensitivity to 0.03 mg./100 gm.

It is of interest to note that no residue was found in the muscle tissue at any time.

Presence of the drug in the brain and heart tissues may be explained by the fact that both have a very extensive vascular supply. Thus, opportunity for the concentration of any material found in the blood was greater. Salzman and Brodie (1956) reported that the concentration in the dog brain was 70 times greater than in the plasma. Since the kidney is an organ of excretion, it was expected that some chlorpromazine hydrochloride or its metabolites would be present. No explanation can be offered at this time for the presence of small amounts of the residual drug in the lung or tongue. Since the levels reported approach the lower

TABLE 4. RESIDUAL CHLORPROMAZINE HYDROCHLORIDE AND CHLORPROMAZINE SULFOXIDE IN BEEF TISSUES [a]

Tissue	Chlorpromazine [b] hydrochloride, mg./100 gm.	Chlorpromazine sulfoxide, [c] mg./100 gm.
Muscle (fresh)	0.01	0.03
Muscle (48 hr. chill)	0.01	0.03
Fat (internal)	0.17	0.03
Brain	0.15	0.03
Spleen	0.17	0.03
Lung	0.18	0.03
Kidney	0.00	0.03
Liver	0.07	0.03
Heart	0.06	0.03
Blood	0.06	0.03
Tongue	0.00	0.03

[a] Chlorpromazine hydrochloride injected intravenously, at a level of 0.8 mg./lb. during a 2½ hour period, slaughtered 4 hr. after last injection.
[b] Sensitivity to 0.01 mg./100 gm.
[c] Sensitivity to 0.03 mg./100 gm.

limits of detectability by the assay procedure, these data do not give an accurate indication of the residue concentration.

When chlorpromazine hydrochloride was injected intravenously, at a level of 0.8 mg./lb. and the animal slaughtered after 4 hours, residues were found in the fat, brain, spleen, lung, liver, heart, and blood (table 4). However, chlorpromazine sulfoxide was not detected in any of the tissues or blood samples.

Residual chlorpromazine hydrochloride was found in the muscle of the chuck after intramuscular injections in this area. It is evident from the data in table 5, that a portion of the drug was present in the bound form. This animal received 4 mg./lb. live body weight in each chuck region after 0.8 mg./lb. had been given intravenously. The injections were purposely large to learn what happens to the drug during the chilling or aging period. No chlorpromazine or its metabolites were found in the

longissimus dorsi muscle even though large amounts were placed in the chuck region. The free and bound chlorpromazine was not metabolized during the holding period of 329 hours at a chill room temperature of 36° F.

Chlorpromazine hydrochloride, when present in muscle tissue at the time of cooking, was found to be converted to chlorpromazine sulfoxide. The sulfoxide was present in a greater quantity in ground beef broiled to an internal temperature of 180° F. than similar beef broiled to 120°, 140°, or 160° F. No chlorpromazine hydrochloride was detected in the cooked meat, indicating that it had all been converted to the sulfoxide form or some other nondetectable metabolite.

TABLE 5. FREE AND BOUND CHLORPROMAZINE IN LEAN MUSCLE OF THE CHUCK [a]

Tissue	Time after slaughter, hr.	"Free" chlorpromazine, mg./100 gm.	"Bound" chlorpromazine, mg./100 gm.	Combined free and bound chlorpromazine, mg./100 gm.
Lean (right)	0	Less than 0.25	3.0	...
Lean (right)	16	Less than 0.25	4.1	...
Lean (right)	48	Less than 0.25	5.1	...
Lean (right)	100	Less than 0.25	3.9	...
Lean (left)	260	.....	...	3.7
Lean (right)	260	.....	...	5.6
Lean (left)	329	.....	...	3.0
Lean (right)	329	.....	...	6.6

[a] Animal received 4 mg./lb. body weight in each chuck after 0.8 mg./lb. had been given intravenously.

Summary

Evidence is presented on the fate of chlorpromazine hydrochloride and chlorpromazine sulfoxide in the bovine. An intravenous injection of 0.19 mg./lb. live weight was not sufficient to produce tranquility; 0.25 mg./lb. visibly depressed docile animals. For more easily excited range stock, a dosage of 0.4 mg./lb. was required.

Approximately 11 to 12% of the injected dose was lost in the urine during the first 24-hours after injection. The urine contained hemoglobin, indicating red blood cell hemolysis. Tissue was damaged at the site of intramuscular injections.

Small quantities of residual chlorpromazine hydrochloride were found in the fat, brain, heart, lung and kidney of those animals receiving 0.4 mg./lb. body weight when slaughtered 8 hours after injection. Animals held for 72 hours had no detectable residual compound in any of the tissues. No residual form of the drug was found in any of the lean tissues, regardless of dose level.

When chlorpromazine hydrochloride was purposely introduced into the

muscle, it was bound in the tissue. Once in this form it was not lost during the normal cooler holding period. Heat was not an adequate means of destroying the drug once it became a tissue contaminant.

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EFFICIENCY OF ALDRIN AND DIELDRIN IN THE FIELD CONTROL OF NATURAL BLOWFLY STRIKE IN SHEEP [1]

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GRAVID females of certain species of blowflies, *Lucilia caesar, Lucilia sericata, Phormia regina,* and *Callitroga macellaria,*[3] lay their eggs in any moist or soiled areas of sheep or lamb fleece. Dirtying or soiling of the fleece about the hind-quarters is conducive to fly "strike" resulting in acute distress and even death of the infested individuals. While this problem is of extreme importance in countries such as South Africa and Australia, it also can assume considerable importance in most of Eastern North America under conditions of wet, warm weather combined with the normal soiling of the rear of most lambs put on fresh, lush pasture at weaning.

Insectary and limited field trials have indicated that aldrin and dieldrin [4] provide control of blowfly strike in some areas of the world where the climate favored their use (Du Toit and Goosen, 1949; Du Toit and Fielder, 1953; Moule *et al.*, 1955; Stones, 1951). A series of field trials on the two substances was conducted under Canadian conditions over a three-year period. These results were compared with those from the use of DDT on the Central Experimental Farm, Ottawa, sheep flock.

Experimental

Experiment No. 1. The entire ewe and lamb flock at the Central Experimental Farm, Ottawa, consisting of 644 individuals in 1954 and 773 in 1955, was used in the project. Routinely, during the first week in June and immediately after shearing, the flock was sprayed with DDT for the control of keds using 6 lb. of 50% wettable powder per 100 gallons of water. Within one week of spraying, the ewes were "jetted" [5] over the dock and breech regions with a 0.5% aldrin solution at from 75 lb. to 100 lb. pressure. Sufficient material was used so that the skin at the base of the wool was dampened. The solution was applied with a common garden-type sprayer having an open-head tank of 4-gallon capacity and fitted with a fine nozzle.

[1] Aldrin and dieldrin contributed by Shell Oil Company of Canada, Limited, Chemical Division.

[2] Assistance in gathering the data and applying treatments was given by R. H. Holt, J. Arcand, and J. Cavanagh, members of the field staff, sheep section, Central Experimental Farm, Ottawa.

[3] Merck Vet. Man. 1955.

[4] These products are not presently licensed for sale in Canada for use on warm-blooded animals. They are licensed for sale in the United States at levels equal to, or higher than, those used here, and application has been made for licensing in Canada.

[5] Application of a fine spray under pressure to a specific area, thereby generally delivering more liquid than by routine spraying.

At the same time the lamb flock, consisting of 312 individuals in 1954 and 387 in 1955, was treated similarly, and randomized within an age, weight, and breed basis into five groups: Group 1—Control (no treatment), group 2—0.5% aldrin, group 3—0.3% aldrin, group 4—0.5% dieldrin, and group 5—0.3% dieldrin.

At the time of jetting all lambs were examined for fly strike and infested animals discarded from the experiment. All groups were segregated and allowed to dry thoroughly and then the entire ewe and lamb flock was run together as a unit until weaning in early August. Following weaning the ram lambs, consisting of about 15 from each experimental group, were segregated as an independent flock, but the remainder were run together until marketed.

At weekly intervals until September 30 all lambs were inspected individually for fly strike and all individuals infested were recorded and given suitable treatment. This procedure was followed for the two years 1954 and 1955.

Experiment No. 2. In 1956, in the light of results from the previous two years, the procedure was amended as follows: The entire band of 847 head was given the customary spraying with DDT using 6 lb. of 50% wettable powder per 100 gallons of water for the treatment of external parasites, but the ewe band was given no further treatment.

The 482 lambs were divided as before within an age, weight and breed basis into three groups: Group 1—Control (no treatment), Group 2—0.3% aldrin, and Group 3—0.3% dieldrin.

In all other respects the flock was given the same care as previously.

Results and Discussion

Several investigators (Du Toit and Fielder, 1953; Du Toit and Goosen, 1949; Stones, 1951; Waterhouse and Scott, 1950) have shown that compounds of the DDT group give excellent control of blowfly strike for very short periods of time, but are limited in their effectiveness because they lack the property of diffusion along the growing wool fibre, and are quickly removed by rain. The normal expectation of blowfly strike in the Central Experimental Farm flock, based on a moving ten-year average, has been slightly more than 7%, ranging from 4% in a dry year to 11% in a year favorable for infestation. This incidence occurred despite the use of DDT as a routine ked control. Du Toit and Fielder (1953) and Moule *et al.* (1955, 1957), have reported that gamma BHC, dieldrin and aldrin do have properties of protracted residual larvicidal action and diffusion, thus protecting the lamb or sheep against fly strike for long periods of time. It was expected that, if the treatments were ineffective, from three to seven animals per group would be struck in 1954, from three to nine in 1955, and from six to seventeen in 1956. The actual results are shown in tables 1 and 2.

TABLE 1. THE EFFECT OF ALDRIN AND DIELDRIN ON THE INCIDENCE OF BLOWFLY STRIKE IN 1954 AND 1955

Group	1954		1955	
	No. of lambs	No. struck	No. of lambs	No. struck
1—Control	64	1	79	3
2—0.5% aldrin	64	0	78	0
3—0.3% aldrin	64	0	78	0
4—0.5% dieldrin	64	0	78	0
5—0.3% dieldrin	60	0	75	0
	$X^2_{64}=18.22$**		$X^2_{56}=20.8$**	

** P<.01.

A chi-square test was applied to the data, the average incidence, based on data of the ten years preceding the experiment, being used as the expected value.

No fly strike occurred in any of the treated groups, indicating that the treatments were effective as applied ($P<0.01$). Fly strike did occur in the control groups each year, but the number of infested individuals in the control groups was consistently below expectation. This was possibly due to the fact that all animals were run together, and had equal chance for initial strike. The lethal effect of the insecticides would probably kill the gravid female fly that contacted treated individuals before the untreated controls, thereby reducing the incidence of ovi-position on the non-treated lambs. As the entire experimental flock ran together, it is also possible that owing to contact enough of the insecticides were transferred to the control animals to cause some repellant action. However, the latter is highly unlikely since, after spraying, all groups were thoroughly dry before being turned together on pastures large enough to preclude forced contact. Also the dock and breech regions are unsuited to a transfer of this nature.

As a further check on the incidence of fly strike, no spraying, other than the normal DDT for the control of external parasites, was done in 1957. During the first week in August there were 23 cases of fly strike in lambs, plus two on yearling wethers. This was slightly in excess of

TABLE 2. THE EFFECT OF ALDRIN AND DIELDRIN ON THE INCIDENCE OF BLOWFLY STRIKE IN 1956

Group	No. of lambs	No. struck
1—Control	160	4
2—0.3% aldrin	160	0
3—0.3% dieldrin	162	0
	$X^2_{66}=26.5$**	

** P<.01.

6% in a single week. All animals were jetted with aldrin at 0.3%, and no further cases were recorded, despite favorable conditions for further infestation.

It can therefore be concluded that aldrin and dieldrin, used at the levels indicated one week after spraying with DDT provide a suitable method of prevention and control of blowfly strike in Eastern Canada, while DDT alone provides no prolonged protection.

Summary

In a series of field trials no cases of fly strike occurred in lambs previously jetted over the dock and breech regions with 0.5% and 0.3% solutions of aldrin or dieldrin during the years 1954, 1955 and 1956 at the Central Experimental Farm, Ottawa. The number infested in the control groups was markedly reduced as compared to previous years, probably due to the gravid female flies contacting treated individuals and being killed prior to completing egg laying. All lambs in all groups had previously been sprayed with DDT to control external parasites. The treatment is a simple, cheap, and effective method of preventing blowfly strike in sheep and lambs in the area tested.

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ARSANILIC ACID IN GROWING-FATTENING RATIONS OF IDENTICAL TWIN CALVES [1]

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VARIOUS forms of arsenic, both organic and inorganic, have been used for many years in veterinary practice as a general tonic and for the treatment of a number of diseases. Several organic arsenicals have been used as growth-promoting agents, the most common of which are 3-nitro-4-hydroxyphenyl-arsonic acid, arsanilic acid (para-aminophenyl-arsonic acid) and sodium arsanilate. These compounds appear to act similarly, although differences in tolerances have been reported (Frost, 1953 and 1956).

Recent research with swine (Bridges *et al.*, 1954; Carpenter, 1951; Hanson *et al.*, 1955; Wallace *et al.*, 1951); sheep (Bucy *et al.*, 1954, 1955); poultry (Bird *et al.*, 1949; Combs *et al.*, 1954; Elam *et al.*, 1953); and rats (Hendrick *et al.*, 1953; Kessler *et al.*, 1954) indicates that species differ in their tolerance to arsenic and their response to non-toxic levels. In general, the addition of arsenic to rations of poultry and swine has improved health and feed efficiency and, to a lesser degree, growth rate.

Other workers in the field of bovine nutrition have noted various responses due to the inclusion of arsenicals in the rations of cattle. Dewey (1953) reported on three feeding trials relative to the addition of sodium arsanilate to rations of dairy calves. A level of 20 mg. per 100 lb. body weight had no effect on weight gains for their first 90 days of life and twice the above level did not affect growth rate when fed for 120 days to four-month-old calves on pasture. In a third experiment five unthrifty calves responded both in growth rate and in general appearance to a daily supplement of 15 mg. of sodium arsanilate per 100 lb. body weight. Graf *et al.* (1952) showed a growth promoting action and a lowered incidence of scours from feeding arsanilic acid to dairy calves. Later studies by Hardison *et al.* (1958) indicated that neither growth rate, feed efficiency nor incidence of scouring was significantly influenced by the presence of 60 or 120 mg. of sodium arsanilate in the daily ration of young dairy calves. Owen *et al.* (1955) using dairy calves reported that the feeding of 3-nitro-4-hydroxyphenyl-arsonic acid at the rate of 57 p.p.m. of the dry matter in the ration increased gains 28% and also improved feed efficiency. The arsenic-fed calves appeared to be more thrifty as denoted by their haircoats. The daily feeding of 50 mg. of arsanilic acid to dairy

[1] The authors are grateful to Abbott Laboratories, North Chicago, Illinois, for furnishing the arsanilic acid used in this study and to L. B. Overby (Abbott Laboratories) who made the tissue arsenic analyses reported herein.

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calves from birth to 23 weeks of age did not affect calf performance in any way in the study made by Bartley *et al.* (1956). Feeding arsenic trioxide to beef heifers at the rate of 18 gm. per 1000 lb. of grain mixture significantly improved gains over a 98-day feeding period (Kline *et al.*, 1946). Recently a daily intake of 345 mg. of 3-nitro-4-hydroxyphenylarsonic acid failed to stimulate weight gains and bring about lowered feed costs in fattening yearling steers (Culbertson *et al.*, 1957). These results are in agreement with those of Minyard *et al.*, (1958) who reported that a dietary level of 454 mg. or arsanilic acid daily was not toxic to beef cattle.

Hancock (1949) made a study of the relative usefulness of identical twin calves in different types of research. In studies involving growth rate as the principal criterion of measurement, one set of identical twins gave data as reliable as two lots each of nine unrelated animals.

The purpose of this study was to evaluate the effects of four levels of arsanilic acid in rations of growing-fattening identical twin beef calves.

Experimental Procedure

Four sets of identical twin calves ranging in age from 351 to 555 days were used (table 1). For a pre-experimental period of 3 weeks each calf was fed 3.0 lb. of Purdue Supplement A and all the corn cobs it would

TABLE 1. THE EFFECT OF DIFFERENT LEVELS OF ARSANILIC ACID ON GROWTH RATE AND FEED UTILIZATION OF IDENTICAL TWIN BEEF CALVES

Twin No.	Initial age, days	Arsanilic acid per day, mg.	Initial weight, lb.	Final weight, lb.	Average daily gain, lb.	Average daily feed, lb.	Feed per lb. gain, lb.
			Summary for first 28 days of arsanilic acid feeding				
467	351	0	462	560	3.50	16.73	4.78
468	351	50	470	556	3.07	16.64	5.42
471	383	0	514	564	1.78	16.90	9.49
472	383	150	510	566	2.00	16.16	8.08
469	358	0	656	750	3.36	18.24	5.42
470	358	250	648	730	2.93	17.32	5.91
473	555	0	703	764	2.17	16.36	7.53
474	555	350	714	754	1.43	14.20	9.93
			Summary for 146 days of arsanilic acid feeding				
467	351	0	462	806	2.36	19.92	8.47
468	351	50	470	817	2.38	20.88	8.79
471	383	0	514	819	2.09	20.12	9.62
472	383	150	510	817	2.06	18.79	8.97
469	358	0	656	1052	2.71	23.57	8.71
470	358	250	648	1051	2.55	23.12	9.08
473	555	0	703	959	1.75	19.23	10.97
474	555	350	714	922	1.42	18.84	13.24

consume daily. During the trial each twin was fed 3.0 lb. of Purdue Cattle Supplement A per day (1.5 lb. twice daily), plus all the cracked shelled corn and ground corn cobs it would consume. The corn and cobs were fed in the following way: the first day each calf received only ground corn cobs plus 3.0 lb. of Supplement A; the second day 1.0 lb. of cracked shelled corn replaced 1.0 lb. of ground cobs; the next day 2 lb. of corn replaced 2 lb. of cobs, etc., until the ratio of corn to cob was 2:1. Thereafter, the ratio remained constant and the total consumption was regulated according to the individual appetite of the calf. In addition, each twin had free access to loose iodized salt and a mineral mixture of 2 parts steamed bonemeal and 1 part iodized salt fortified with 1 oz. of cobalt sulphate per 100 lb. One twin of each set received the basal ration plus arsanilic acid in amounts shown in table 1. The arsanilic acid was supplied in a commercial product which contained 20% arsanilic acid by weight. The calves were weighed weekly for the first seven weeks and bi-weekly thereafter.

At the end of the 146-day feeding period all calves were marketed, slaughtered, graded by a Federal grader and tissue samples were collected for arsenic analyses. The arsanilic acid feeding was terminated 20 hours prior to slaughter. The arsenic determinations were made on the dried tissue samples by the method of Evans and Bandemer (1954).

Results and Discussion

Results in table 1 show that growth rate was not affected by the daily feeding of 50 or 150 mg. of arsanilic acid but was reduced 0.16 and 0.33 lb. daily, for the 146-day feeding period, by 250 mg. and 350 mg., respectively. The reduction in rate of growth was most marked during the first 28 days of the experiment. Thus, the response agrees with the first two experiments of Dewey (1953) and the experiment of Culbertson *et al.* (1957).

Appetite was reduced by the two highest levels (250 and 350 mg.) of arsanilic acid (table 1). However, this reduction in appetite was not as great at the end of the 146-day feeding period as during the first 28 days. Thus, it appears that the calves became more tolerant to the high levels of arsanilic acid with time.

Feed efficiency (pounds of feed per pound of gain) was improved only by the 150 mg. level (table 1). At this level the feed saving was 5.7%. Feed efficiency decreased by 17% in the calf receiving 350 mg. of arsanilic acid. Even though statistical analysis of the data is not possible with the experimental design used in this experiment, it appears that some importance should be attached to the marked reduction in feed efficiency in the calf fed this high level of arsanilic acid. Except for periodic daily variations in feed consumption, all calves remained on feed throughout

TABLE 2. EFFECT OF FEEDING ARSANILIC ACID ON SHRINK AND CARCASS GRADES OF IDENTICAL TWIN BEEF CALVES

Twin No.	Arsanilic acid per day, mg.	Transit shrink, %	Cooler shrink, %	U.S. Goverment grades
467	0	2.6	1.5	Med.—Choice
468	50	2.1	1.3	High—Choice
471	0	4.2	0.9	High—Good
472	150	3.9	1.3	Low—Choice
469	0	3.0	1.5	Low—Good
470[a]	250	1.6	1.2	Med.—Good
473	0	3.5	1.0	Low—Choice
474	350	2.4	1.3	Low—Good

[a] No. 470 was given the grade medium good stag.

the feeding period. No toxicity symptoms were noted in any calf at any time.

Weight loss during shipment (table 2) was reduced by all levels of arsanilic acid, but the differences were largest in the calves fed either 250 or 350 mg. daily. Cooler shrink varied only slightly between animals. The U. S. Government carcass grades were one-third of a grade higher for the calves fed 50, 150 and 250 mg. of arsanilic acid daily but one complete grade lower for the twin fed 350 mg. The latter was expected because of the growth rate obtained, but the reason for the upgrading of the carcasses by the other three levels is not understood. This result suggests a need for further study.

Table 3 summarizes the arsenic content of the tissues. The liver, kidney and rumen wall contained the greatest amounts of arsenic, the amount increasing with each increase in the dietary arsanilic acid level up to 250 mg. per day. The tissue arsenic content on the 250-mg. level was less than one-half that reported by Hanson *et al.* (1956) for pigs fed rations containing 30 mg. of arsanilic acid per lb. of feed up to two days before slaughter. Arsenic was not detected in the skin, heart or fat samples.

TABLE 3. ARSENIC CONTENT OF TISSUES[a]

Calf	Arsanilic acid per day, mg.	Liver	Kidney	Spleen	Muscle	Rumen wall
467	0	0	0	0	0	0
468	50	0.30	0.15	0	0	0.09
471	0	0	0	0	TR	0
472	150	0.36	lost	0.19	0	0.20
469	0	0	0	TR	TR	TR
470	250	0.67	0.18	0.14	0.10	0.21
473	0	0	0	0	0	0
474	350	0.56	0.22	0	0.11	0.16

[a] No arsenic was detected in the skin, heart or fat samples taken from each animal. Values are in micrograms per gram fresh tissue.

No treatment differences were noted in the water or ash content of the 12th rib eye (data not shown).

Summary

Four sets of identical twin beef calves were fed for a period of 146 days on a growing-fattening ration to determine the effect of different levels of dietary arsanilic acid on performance. One twin of each set was fed either 50, 150, 250 or 350 mg. of arsanilic acid daily.

Growth rate was not affected by the daily feeding of 50 or 150 mg. of arsanilic acid but was reduced at the 250 and 350 mg. levels 0.16 and 0.33 lb. daily, respectively. Appetite was reduced slightly by the 150, 250 and 350 mg. levels and increased a similar amount by the 50 mg. level. The most significant change in feed efficiency was the decrease resulting from feeding 350 mg. of arsanilic acid. Transit shrink was reduced by all four levels of arsanilic acid. The carcass grades were one-third of a grade higher for the calves fed 50, 150 and 250 mg. of arsanilic acid over their twin controls, but one grade lower for the twin fed 350 mg.

The liver, kidney and rumen wall contained the greatest amounts of arsenic, and the amount increased with the dietary increases of arsanilic acid up to 250 mg. per day.

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DIETHYLSTILBESTROL AND LENGTH OF PRELIMINARY PERIOD IN THE UTILIZATION OF CRUDE BIURET AND UREA BY LAMBS. II. VARIOUS ASPECTS OF NITROGEN METABOLISM

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PREVIOUS reports from the West Virginia Station (Smith *et al.*, 1957; Welch *et al.*, 1957; McLaren *et al.*, 1959), emphasized the importance of the length of preliminary period on the retention of absorbed nitrogen by lambs fed rations containing high percentages of non-protein nitrogen (NPN). These reports also showed that feeding 2 mg. per day of diethylstilbestrol (DES) markedly reduced the length of time required for the attainment of maximum nitrogen utilization. Since the nature of this effect of DES in the ruminant is not known, the investigations described in this report were undertaken to explore the manner of action of DES by examining its influence upon various aspects of nitrogen metabolism and thyroid activity in the lamb.

Experimental Procedure

This work consisted of four nitrogen metabolism trials with lambs, with additional chemical analyses on blood and urine. In Trials 1, 2 and 3 the lambs were fed semi-purified rations containing 1.6% nitrogen, two-thirds of which was supplied by non-protein nitrogen (NPN) sources. To study the endogenous nitrogen metabolism, lambs were fed semi-purified rations containing only 0.28% nitrogen in Trial 4. The constituents and composition of these rations are given in table 1. Pre-trial management of the lambs, procedures in feeding and getting the lambs on a constant feed intake, and techniques for collecting, sampling and analyzing the feed and excreta were the same as discussed by McLaren *et al.* (1959).

Trial 1. In this trial the lambs were fed rations consisting of wheat straw, cane molasses and a concentrate mixture which varied only in the compounds used to furnish supplemental nitrogen, both in the presence and in the absence of DES. Four lambs were randomly assigned to each of the following rations designated according to the source of supplemental nitrogen: (1) urea, 100%, (2) urea, 50% and crude biuret 50%, and (3) crude biuret, 100%. Two lambs on each of these rations were randomly selected to receive 2 mg. of DES per day.

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Urea and ammonia nitrogen concentrations were determined on samples of blood collected from lambs after they had received the experimental ration for 0, 15, 35 and 55 days. Blood was collected approximately 3 hours after feeding. Blood urea nitrogen and ammonia nitrogen were determined according to the procedure of Van Slyke and Cullen (1914). The apparent urinary biuret excretion of lambs after 15 and 35 days in

TABLE 1. AVERAGE DAILY AMOUNTS AND PERCENTAGE COMPOSITION OF RATIONS

Ration designation	100% Urea	50% Urea 50% Crude biuret	100% Crude biuret	100% Crude biuret	Low nitrogen
Trial number	1	1	1	2 and 3	4
Ration constituents, gm.					
Wheat straw	440.0	*	*	*	335.0
Cane molasses (78% solids)	170.0	*	*	*	142.0
Concentrate mixture	200.0	*	*	*	168.0
Purified soybean protein [a]	13.2	*	*	*	0.0
Urea	18.4	9.2	....	....	0.0
Crude biuret [b]	....	9.2	18.4	18.4	0.0
Corn starch	76.0	*	*	*	77.0
Dextrose	32.4	*	*	*	40.6
Corn oil	29.4	*	*	*	24.7
Mineral mixture [c]	27.3	*	*	*	22.9
Vitamin A-D oil [d]	2.6	*	*	*	2.2
Choline	0.7	*	*	*	0.6
Vitamin supplement [e]	+	+	+	+	+
Total, gm.	810.0	*	*	*	645.0
Composition, dry matter basis, %					
Organic matter	92.5%	92.75	92.72	93.35	93.02
Protein (N x 6.25)	9.57	9.62	9.66	10.20	1.75
Ether extract	5.12	5.14	5.16	5.12	5.50
Crude fiber	25.22	24.97	25.10	24.79	23.12
N-free extract	52.66	53.02	52.80	53.24	62.65

* Indicates same amount as in the 100% urea supplemented ration fed in Trial 1.

[a] Drackett assay protein C-1. The Drackett Products Company, Cincinnati 32, Ohio.

[b] A mixture containing biuret (40.0%), urea (45.5%), triuret (6.7%), cyanuric acid (7.6%) and water (0.3%). The crude biuret and feeding urea were supplied by Allied Chemical and Dye Corp., Nitrogen Div., New York, N. Y.

[c] Composition of mineral mixture as given by Thomas *et al.* (1951).

[d] Nopco XX. National Oil Products Company, Harrison, New Jersey. Stated to contain no less than 2250 USP units of vitamin A and 300 IC units of vitamin D per gram.

[e] Two hundred grams of concentrate mixture of the ration furnished 1.8 mg. each of thiamine and riboflavin and 8.0 mg. of alpha tocopherol. These materials were supplied by L. Michaud, Animal Research Division, Merck, Sharp and Dohme, Rahway, New Jersey.

Trial 1 was determined by the method of Johnson and Swanson (1952). Digestion and nitrogen metabolism data from this trial were reported by McLaren *et al.* (1959).

Trial 2. In this trial eight lambs were fed for 60 days a ration in which crude biuret supplied 100% of the supplemental nitrogen. Four lambs received 2 mg. of DES per day and four served as controls. At the completion of the trial samples of blood were collected from all eight lambs and analyzed for plasma protein-bound iodine (PBI) to determine the effect of DES on thyroid secretory activity. The alkaline ashing procedure

of Brown *et al.* (1952) was used for all PBI analyses. Digestion and nitrogen metabolism data obtained in this trial were reported by McLaren *et al.* (1959).

Trial 3. This trial was designed to determine the extent of the "carry-over" effect of DES on digestion and nitrogen retention after withdrawing it from the ration. At the completion of Trial 2, in which half of the lambs received DES for 60 days, feeding of this adjuvant was discontinued. The collection of feces and urine was begun immediately after the last collection of Trial 2 and was continued through two successive 10-day periods.

Trial 4. This trial was designed to determine the effect of DES on the metabolic fecal nitrogen and the endogenous urinary nitrogen. In addition the allantoin and creatinine moieties of the endogenous urinary nitrogen were determined. Creatinine was determined by the method of Clark and Thompson (1949) and allantoin by the method of Larson (1932).

Eight wether lambs were fed the low-nitrogen ration shown in table 1. Four lambs received 2 mg. of DES daily and four served as controls. Twenty-five days were allowed for adjustment of the lambs to the low-nitrogen ration which contained 0.28% nitrogen. Upon completion of the adjustment period feces and urine were collected during a 5-day period. This was followed immediately by a second 5-day collection period with two lambs from each group. Plasma protein-bound iodine was determined on blood collected at the end of the first 5-day collection period.

The total urinary nitrogen excretion on the low-nitrogen ration is referred to as endogenous urinary nitrogen and is expressed as milligrams of nitrogen per kilogram of body weight (mgN/kg.). The metabolic fecal nitrogen is expressed as grams of fecal nitrogen per 100 grams of dry matter intake (gmN/100 gm. D.M.).

Since the nitrogen in wheat straw was not completely digested it was considered advisable to correct the total fecal nitrogen for fecal wheat straw nitrogen to obtain metabolic nitrogen. This correction was made by the method of Mukherjee and Kehar (1949). The fresh feces were placed on a 100-mesh screen, washed with tap water and the undigested wheat straw fibers recovered were analyzed for nitrogen. All data were subjected to analysis of variance according to Snedecor (1946).

Results and Discussion

Trial 1. The blood concentrations of urea and ammonia nitrogen are given in table 2. The analyses of variance of these data are presented in table 3. It is apparent from tables 2 and 3 that the concentration of blood urea nitrogen is depressed ($P<.01$) by increasing the number of days on ration, proportion of biuret, and DES. Increasing the number of days on ration caused a significant ($P<.05$) increase in blood ammonia nitrogen concentration, but DES significantly ($P<.05$) depressed it.

TABLE 2. BLOOD UREA AND AMMONIA NITROGEN LEVELS OF LAMBS FED NPN COMPOUNDS. TRIAL 1

Ration NPN supplement	DES fed	Blood urea nitrogen after days on ration [a]				Blood ammonia nitrogen after days on ration [a]			
		0	15	35	55	0	15	35	55
	mg./day	mg. %	mg. %	mg. %	mg. %	mg. %	mg. %	mg. %	mg. %
100% urea	0	15.6	15.4	13.6	15.0	0.34	0.71	0.59	1.03
100% urea	2	19.0	14.5	13.8	11.1	0.30	0.73	0.53	0.59
50% urea, 50% crude biuret	0	14.7	14.2	21.9	15.8	0.27	0.79	0.49	0.91
50% urea, 50% crude biuret	2	19.6	15.9	15.7	13.1	0.31	0.53	0.45	0.63
100% crude biuret	0	16.3	13.3	13.5	12.8	0.30	0.59	0.52	0.59
100% crude biuret	2	14.6	12.3	10.7	6.6	0.31	0.59	0.41	0.63

[a] Two lambs were used per treatment.

Inspection of the blood ammonia and urea nitrogen data (table 2) reveals aspects of nitrogen metabolism which may provide some understanding of the effect of time and of DES in promoting increased retention of absorbed nitrogen. The blood ammonia nitrogen concentration was significantly increased as the number of days on the NPN supplemented rations (Time) was increased. However, this effect was influenced by a Time x DES interaction (table 3). Although blood ammonia nitrogen was increased with time, when DES was fed this increase was less. Substitution of crude biuret for urea in the ration did not significantly decrease blood ammonia nitrogen.

When the blood urea nitrogen data are considered an entirely different picture is obtained. These data indicate that the number of days on the ration and substitution of crude biuret for urea caused a significant depression in the concentration of blood urea nitrogen. However, as in

TABLE 3. ANALYSIS OF VARIANCE OF BLOOD UREA AND AMMONIA NITROGEN DATA. TRIAL 1

Source	Degrees of freedom	Mean square blood urea nitrogen	Mean square blood ammonia nitrogen
		mg. %	mg. %
Total	47		
Time (T)	3	36.50**	0.092*
Biuret level (B)	2	60.22**	0.050
DES	1	19.97*	0.106*
T x B	6	6.67	0.008
T x DES	3	25.00*	0.328**
B x DES	2	7.61	0.018
Error	30	6.44	0.023

* $P<.05$.
** $P<.01$.

the case of blood ammonia nitrogen, an interaction of Time x DES also occurred. The depression of blood urea nitrogen was influenced very slightly by increasing the number of days of feeding the NPN supplement without DES. However, when DES was present in the ration, the depression with time was very marked.

The lack of increase in blood urea nitrogen despite elevated blood ammonia levels might suggest more efficient utilization of the ammonia by the tissues for the synthesis of non-essential amino acids. Studies by Rose *et al.* (1949), Lardy and Feldott (1950), and Rechcigl, Loosli and Williams (1957) have shown that a variety of non-specific nitrogen sources may be utilized by animal tissues for the synthesis of non-essential amino

TABLE 4. AVERAGE PLASMA PROTEIN-BOUND IODINE (PBI) OF LAMBS FED CRUDE BIURET AND LOW-NITROGEN RATIONS

Trial and ration designation	DES supplementation	Lambs per treatment	Average daily dry matter intake	Ration protein (N x 6.25)	PBI levels per 100 ml. blood
Trial 2			gm.	%	mcg.
100% crude biuret	No	4	727	10.20	9.2±0.4[a]
" " "	2 mg./day	4	726	10.01	9.2±0.6
Trial 4					
Low-nitrogen	No	4	576	1.75	9.9±0.6
" "	2 mg./day	4	510	1.76	14.7±5.3

[a] Standard error.

acids. The influence of DES in reducing both blood ammonia and urea nitrogen when considered in association with the improvement seen in the retention of absorbed nitrogen, suggests that DES acts to promote better utilization of non-specific nitrogen by the tissues.

The excretion of apparent urinary biuret after 15 and 35 days was not significantly different so the data for both periods at each level of crude biuret intake were pooled. Average apparent urinary biuret excretion in milligrams per day was 494, 784, and 1188, respectively, for lambs fed rations containing 0, 50 and 100% of the supplementary NPN as crude biuret. A significant direct relationship ($P<.05$) existed between the level of crude biuret in the ration and that found in the urine. This relationship was not influenced by DES. It is interesting to note that urinary biuret excretion, after correcting for the amount excreted by lambs fed no crude biuret, amounted to only 4% of the biuret ingested. This was a much smaller percentage loss than that reported by Hatfield *et al.* (1955) for steers.

Trial 2. Plasma protein-bound iodine (PBI) values for the lambs in Trial 2 are presented in table 4. DES did not significantly affect PBI

values. The mean PBI value for all eight lambs on Trial 2 was 9.2 mcg. per 100 ml. of blood.

Trial 3. McLaren *et al.* (1959) have presented data to show that the feeding of DES resulted in an improvement in nitrogen utilization and a depression in nutrient digestibility. The results of Trial 3, which are presented in table 5, indicate that these effects of DES feeding could not be detected 10 or 20 days after this material had been withdrawn from the ration.

TABLE 5. THE EFFECT OF PREVIOUS DES FEEDING ON DIGESTION AND NITROGEN METABOLISM. TRIAL 3

	First 10-day		Second 10-day	
Collection period treatment	DES not previously fed	DES fed 60 days prior to collection	DES not previously fed	DES fed 60 days, then 10 days no DES
Average dry matter intake, gm.	723	722	726	725
Ration protein (N x 6.25), %	10.22	10.04	10.08	9.89
Average dig. coefficients				
Organic matter	63.2	61.9	61.8	61.4
Protein (N x 6.25)	70.4	69.7	70.2	70.2
Crude fiber	52.9	50.8	52.4	51.4
Nitrogen intake, gm.	11.84	11.62	11.69	11.41
Fecal nitrogen, gm.	3.51	3.53	3.50	3.42
Urinary nitrogen, gm.	7.23	7.21	7.02	7.15
Nitrogen balance, gm.	+1.10	+0.88	+1.17	+0.90
Absorbed[a] nitrogen retained, %	46.9	45.5	48.2	46.0

[a] "True" digested.

Trial 4. Diethylstilbestrol when fed to lambs on a low-nitrogen ration did not influence metabolic fecal nitrogen or endogenous urinary nitrogen. The metabolic fecal nitrogen values expressed as gm. N per 100 gm. dry matter intake are presented in table 6. The values for the DES treated and control lambs were 0.495 and 0.469, respectively. The difference between these values was not significant ($P>.05$) so that metabolic fecal nitrogen values for all lambs were pooled. This gave a value of 0.480 ± 0.008. After correcting for undigested nitrogen in the fecal wheat straw fibers the metabolic fecal nitrogen values were 0.444 and 0.427 for the DES treated and control lambs, respectively. The difference between these values was not significant ($P>.05$). Pooling of the data resulted in a mean corrected metabolic fecal nitrogen of 0.435 ± 0.023 gm. per 100 gm. dry matter intake.

The urinary nitrogen metabolism data obtained with lambs on the low-nitrogen ration are presented in table 7. The endogenous urinary nitrogen, expressed as mg. N per kg. body weight was 34.2 and 33.8 for the DES-fed

TABLE 6. AVERAGE DAILY METABOLIC FECAL NITROGEN EXCRETION OF LAMBS FED LOW-NITROGEN RATIONS WITH AND WITHOUT DES. TRIAL 4

Lamb no.	Period number	DES fed	Dry matter intake	Ration nitrogen	Total fecal nitrogen	Estimated metabolic fecal nitrogen[a]	Nitrogen in wheat straw	Wheat straw fecal nitrogen	Corrected fecal nitrogen	Corrected metabolic fecal nitrogen
		mg.	gm.	%	gm.	gm.	gm.	gm.	gm.	gm.
1	1	0	687	0.28	3.15	0.459	1.58	0.27	2.88	0.419
2	1	0	687	0.28	3.24	0.472	1.58	0.18	3.06	0.445
5	1	0	487	0.27	2.18	0.448	1.04	0.32	1.86	0.382
6	1	0	527	0.26	2.75	0.522	1.12	0.27	2.48	0.471
1	2	0	601	0.30	2.81	0.468	1.48	0.27	2.54	0.423
2	2	0	687	0.28	3.06	0.445	1.58	0.18	2.88	0.419
Mean—Lambs not fed DES						0.469				0.427
3	1	2	625	0.28	2.97	0.475	1.44	0.30	2.67	0.427
4	1	2	566	0.28	2.98	0.527	1.30	0.23	2.75	0.486
7	1	2	401	0.26	2.02	0.504	0.85	0.32	1.70	0.424
8	1	2	436	0.26	2.01	0.461	0.93	0.23	1.78	0.408
3	2	2	609	0.30	3.02	0.496	1.50	0.30	2.72	0.447
4	2	2	594	0.30	3.02	0.508	1.46	0.23	2.79	0.470
Mean—Lambs fed DES						0.495				0.444
Mean—All lambs						0.480±0.008	1.32	0.26[b]		0.435±0.023

[a] Metabolic fecal nitrogen expressed in gm. N per 100 gm. dry matter intake.
[b] Nitrogen of wheat straw recovered in feces equaled 19.7% of that in the wheat straw ingested.

TABLE 7. AVERAGE DAILY NITROGENOUS CONSTITUENTS OF THE URINE OF LAMBS FED LOW-NITROGEN RATIONS WITH AND WITHOUT DES. TRIAL 4

Lamb no.	Period number	DES fed per day	Lamb weight	Urinary nitrogen	Endogenous urinary nitrogen[a]	Creatinine N		Allantoin N	
						Daily excretion	Creatinine coefficient[b]	Daily excretion	Allantoin coefficient[c]
		mg.	kg.	gm.	mg./kg.	gm.	mg. N/kg.	gm.	mg. N/kg.
1	1	0	36.5	1.38	37.8	0.297	7.9	0.439	12.0
2	1	0	37.5	1.26	33.6	0.305	9.1	0.517	13.8
5	1	0	38.6	1.16	30.0	0.275	7.8	0.404	10.5
1	2	0	36.5	1.30	35.6				
2	2	0	37.5	1.20	32.0				
Mean—Lambs not fed DES					33.8		8.3		12.1
3	1	2	35.7	1.22	34.2	0.297	8.3	0.439	12.3
4	1	2	35.1	1.18	33.6	0.275	7.8	0.425	12.1
8	1	2	40.7	1.56	38.3	0.371	9.1	0.319	7.8
3	2	2	35.7	1.12	31.4				
4	2	2	35.1	1.18	33.6				
Mean—Lambs fed DES					34.2		8.4		10.7
Mean—All lambs					34.1		8.4		11.4

[a] Endogenous urinary nitrogen is expressed as mg. of nitrogen per kg. of body weight per day.
[b] Creatinine coefficient is the urinary creatinine N excreted per kg. of body weight per day.
[c] Allantoin coefficient is expressed as the urinary allantoin N excreted per kg. of body weight per day.

and control lambs, respectively. The mean endogenous urinary nitrogen values for all lambs was 34.0±0.08 mg. per kg. body weight.

DES supplementation was without significant effect on creatinine and allantoin excretion (table 7). The excretion of creatinine nitrogen which is expressed as mg. per kg. body weight per day (creatinine coefficient) was 8.4 for the DES treated and 8.3 for the control group. Allantoin nitrogen excretion expressed as mg. per kg. body weight per day was 10.7 and 12.1 for the DES and control lambs, respectively. The difference between means was not significant ($P>.05$) so all allantoin values were pooled and the mean value was 11.4.

The mean plasma protein-bound iodine values of lambs on the low-nitrogen ration were 9.9 and 14.7 mcg. per 100 ml. of blood for the DES treated and control lambs, respectively, (table 4) but the difference between the means was not significant.

The possibility that orally administered DES might influence the retention of absorbed nitrogen by the tissues as the result of indirect action through the thyroid gland was suggested by the report of Mukherjee and Mitchell (1951). These authors fed thyroprotein to dairy calves and observed an increase in the excretion of endogenous urinary nitrogen. The lack of significant difference ($P>.05$) in plasma PBI values between lambs fed DES and control rations containing either high or low percentages of nitrogen would tend to preclude the possibility that DES influences nitrogen metabolism by acting upon the thyroid gland. This obseration agrees with that of Shroder and Hansard (1958).

Summary

Various aspects of nitrogen metabolism of lambs were considered in an attempt to ascertain the nature of the effect of DES and length of preliminary period on the retention of absorbed nitrogen.

DES was without effect on the excretion of metabolic fecal nitrogen, endogenous urinary nitrogen, creatine, or allantoin. The mean metabolic fecal nitrogen corrected for undigested fiber nitrogen was 0.435±0.023 gm. N per 100 gm. dry matter intake. The mean endogenous urinary nitrogen value was 34.0±0.08 mg. N per kg. body weight. The mean excretion values for creatine and allantoin expressed as mg. N per kg. body weight per day were 8.4 and 11.4, respectively.

DES did not significantly influence plasma PBI values of lambs on high or low nitrogen rations.

The pattern of blood ammonia and urea nitrogen levels, urinary excretion of biuret, plasma PBI values and associated digestion and nitrogen metabolism data make it appear that DES and time influence the retention of absorbed nitrogen through direct action on the tissues to promote better utilization of non-protein nitrogen.

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INFLUENCE OF FATTY ACIDS UPON DIGESTIBILITY OF RATION COMPONENTS BY LAMBS AND UPON CELLULOSE DIGESTION *IN VITRO* [1, 2]

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THE depressing effect of added fat upon dry matter, organic matter and crude fiber or cellulose digestibility has been reported (Swift *et al.*, 1947; Brooks *et al.*, 1954; Ward *et al.*, 1957; Brethour *et al.*, 1958) in rations containing corn cobs or cottonseed hulls. Brooks *et al.* (1954) and Pfander and Verma (1957) suggested the coating of the feed particles with fat as one reason for this depressing effect. Additions of alfalfa ash (Brooks *et al.*, 1954; Ward *et al.*, 1957) and of excess calcium (White *et al.*, 1958) to rations have alleviated these depressing effects.

The work reported herein was done to compare the effects of a neutral fat and fatty acids upon digestion by lambs of a low ash, high corn cob ration. In view of the results of the first of these studies, further trials were conducted *in vivo* and *in vitro* to determine the effects of carbon-chain length and degree of saturation of fatty acid upon digestibility. Additional *in vitro* studies were conducted to determine the effects of C_2 to C_{18} fatty acids and glycerol upon cellulose digestion by rumen microorganisms.

Experiment Procedure

Trial 1, Metabolism. Nine western crossbred wether lambs weighing an average of 66 lb. were randomly divided into three groups, each of three lambs, and randomly assigned to the following rations: (1) basal, (2) basal + 5% corn oil and (3) basal + 5% fatty acids. The fatty acids were a distilled animal type whose approximated composition was 2% myristic acid, 26% palmitic acid, 16% stearic acid, 48% oleic acid and 8% linoleic acid. The basal ration, patterned after Ward *et al.* (1957) was mixed prior to starting the experiment and contained, in percent, ground corn cobs, 46; ground shelled corn, 32; corn gluten meal, 20; salt, 1; and dicalcium phosphate, 1. The daily ration contained, in addition, 0.4 gm. of a vitamin A-D supplement [3] and 4.4 mg. cobalt sulfate. Daily allowance of the basal ration was 700 gm. which was fed in equal portions twice daily. The basal ration contained 92.6% dry matter. The chemical composition on a dry matter basis was organic matter, 96.3%;

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[2] All the fatty acids used in this study were supplied by Mr. B. M. Shinn of Armour and Company, Chicago, Illinois.

[3] Quadrex, containing 10,000 I.U. of vitamin A and 1,250 I.U. of D_2 per gram, was supplied by Dr. M. Hochberg of the NOPCO Chemical Company, Harrison, New Jersey.

protein, 12.7%; cellulose, 25.9%; ether extract, 1.3%; and ash, 3.7%. The corn oil and fatty acids were added to the basal ration at each feeding. The trial was repeated with the same animals being randomly reallotted after a 10-day rest period in which they were fed alfalfa hay.

The lambs were placed in metabolism cages of a raised wire-floor type. Water was available except when the lambs were eating. A 10-day preliminary period preceded a 10-day collection period. Feces were collected in bags (Garrigus and Rusk, 1939) and dried for 48 hours at approximately 70° C. in a forced draft oven. After equilibration with moisture in the air, they were mixed and samples were ground for analysis. Urine was filtered through glass wool and collected in glass jugs containing acid (10 ml. of a mixture of equal parts HCl and water). The daily urine collection was diluted to a constant volume and an aliquot stored under refrigeration until analyzed. Cellulose was determined in the feed and feces by the method of Crampton and Maynard (1938). Other chemical analyses were made by AOAC (1950) methods. Statistical treatment of the data was by the method of analysis of variance and orthogonal comparisons (Snedecor, 1956).

Trial 2, Metabolism. Twenty-four western crossbred wether lambs weighing an average of 63 lb. were randomly allotted to four groups of six each, to which the following rations were fed: (1) basal, (2) basal + 5% lauric acid, (3) basal + 5% stearic acid and (4) basal + 5% oleic acids. The basal ration contained 91.1% dry matter. The chemical composition on a dry matter basis was organic matter, 96.6%; protein, 13.3%; cellulose, 26.5%; ether extract, 1.2%; and ash, 3.4%. The purity of the lauric, stearic, and oleic acids as stated by manufacturer was 96, 93 and 86%, respectively. The lambs would not consume the ration containing 5% lauric acid so the acid was added at the 1% level. The trial was run in two replications of three lambs per treatment, different lambs being used in each replication. All other procedures have been described in trial 1.

Trial 3, Cellulose Digestion In Vitro. An *in vitro* rumen fermentation procedure was used to determine the effect of the previously described lauric, stearic and oleic acids on percent cellulose digested in 26 hours. The procedure used was similar to that reported by Cheng *et al.* (1955) with the exception that the bacteria were suspended in the digestion medium after they were first centrifuged in the Sharples super-centrifuge; they did not go through the washing procedure. Rumen liquor was obtained from a steer fitted with a permanent fistula and maintained on a diet of alfalfa hay, corn cobs, corn, soybean meal and minerals. Three liters of rumen liquor were strained through 4 layers of cheesecloth and then centrifuged at 2,000 r.p.m. for 2 minutes. The supernatant was strained through 8 layers cheese cloth again to remove coarse feed particles. The sediment, collected on a celluloid liner of a Sharples super-centrifuge, operated at 25,000 r.p.m. and suspended in 900 ml. digestion medium

(Hubbert *et al.*, 1958), was used as the rumen bacteria digestion medium for the fermentation.

Each 75-ml. test tube contained 20 ml. of rumen bacteria digestion medium and 500 mg. cellulose.[4] The fatty acids were added at levels of 25 and 50 mg. per 20 ml. of medium. The fatty acids were dissolved in ether and absorbed on 500 mg. cellulose after which the ether was removed on a steam plate. Two replicates were carried out in which four tubes were used per treatment and six tubes per control.

Trial 4, Cellulose Digestion In Vitro. Tests were made of the effects of chemically pure fatty acids and glycerol upon cellulose digestion by rumen microorganisms *in vitro*. A completely randomized design was used within each test with six tubes per treatment. In the first test, acetic, butyric, valeric, caporic and caprylic acids were added to the digestion tubes at the level of 25 mg. per 20 ml. of medium. In the second test, caprylic, capric, lauric, myristic, and palmitic acids were added, and in the third test, palmitic, stearic, oleic, and linoleic acids, and glycerine were added (25 mg. per 20 ml. medium). In each test cellulose digestion was determined in control tubes. Data within each study were subjected to analysis of variance (Snedecor, 1956) and multiple range test (Duncan, 1955).

Results and Discussion

Trials 1 and 2. The average digestion coefficients and nitrogen balance data for trials 1 and 2 are given in table 1. The added fat appeared to decrease appetite; the lambs fed either corn oil or fatty acids were slower in consuming their ration than the controls. Corn oil and the mixture of fatty acids significantly ($P<0.01$) decreased the digestibility of dry matter, organic matter, cellulose, and ash, and decreased the digestibility of protein ($P<0.05$). Both corn oil and the fatty acid mixture significantly increased the digestibility of ether extract ($P<0.01$). Corn oil decreased nitrogen retention ($P<0.01$); fatty acids did not. The results with corn oil were similar to those of Ward *et al.* (1957).

The addition of the separate fatty acids significantly ($P<0.01$) decreased digestibility of dry matter, organic matter and cellulose and increased digestibility of ether extract. Stearic and oleic acids tended to decrease digestibility of protein. The addition of 5% stearic and oleic acids decreased ($P<0.05$) the digestibility of dry matter and organic matter more than the addition of 1% lauric acid. Oleic acid decreased the digestibility of cellulose more than the lauric or stearic acids. The digestibility of ash was lower in the stearic and oleic acid rations than in the lauric acid ($P<0.01$) or control rations. Oleic acid decreased digestibility of ash more than stearic acid ($P<0.05$). The digestibility of ether extract was lower ($P<0.05$) in the stearic acid ration than in the oleic and lauric acid rations.

[4] Solka-floc.

TABLE 1. DIGESTIBILITY AND NITROGEN BALANCE DATA OBTAINED WITH LAMBS FED CORN OIL AND FATTY ACIDS [a]

Ration and product [b]	Basal	Basal + corn oil	Basal + fatty acids	Basal	Basal + lauric acid	Basal + stearic acid	Basal + oleic acid
Trial no.	1	1	1	2	2	2	2
Digestibility of:							
Dry matter, %	67.7	62.8	63.0	67.9	66.4	62.6	61.4
Organic matter, %	68.1	63.4	63.7	69.1	67.3	63.6	62.5
Protein, %	73.3	69.4	70.5	74.3	73.7	71.7	71.4
Ether extract, %	57.6	81.7	86.1	26.5	64.7	53.4	67.7
Cellulose, %	55.4	48.6	47.4	62.4	54.9	53.8	47.7
Ash, %	56.9	47.1	46.4	33.3	39.2	29.6	18.1
Nitrogen balance							
Nitrogen intake, gm.	13.23	13.23	13.23	13.54	11.77	13.61	13.10
Fecal nitrogen, gm.	3.54	4.04	3.91	3.46	3.12	3.84	3.74
Urine nitrogen, gm.	6.43	7.04	6.31	7.02	5.71	6.79	7.00
Nitrogen retained, gm.	3.26	2.15	3.01	3.06	2.94	2.98	2.36
As percent of intake	24.7	16.2	22.8	22.4	24.0	21.9	18.4

[a] Values are on an average daily basis.
[b] Because of feed refusal the number of lambs on each ration in the above order was 6, 6, 5, 6, 6, 5, and 6, respectively.

All of the acids, particularly lauric, were unpalatable to the lambs. Four of the lambs fed the lauric acid ration refused a small amount of feed. The low level of lauric acid fed, probably accounts for the higher apparent digestibility of the ash and other ration components.

TABLE 2. EFFECTS OF VARIOUS FAT COMPONENTS UPON CELLULOSE DIGESTION *IN VITRO*

Treatment	Digestion, %	Treatment [a]	Digestion, %
Trial 3		Trial 4	
Control	36.2	Control	40.4
Lauric acid, 25 mg.	12.2	Acetic acid	42.6
Lauric acid, 50 mg.	11.7	Butyric acid	46.5
Stearic acid, 25 mg.	15.8	Valeric acid	45.2
Stearic acid, 50 mg.	15.0	Caproic acid	41.4
Oleic acid, 25 mg.	24.7	Caprylic acid	22.3
Oleic acid, 50 mg.	22.7	Capric acid	12.9
		Lauric acid	13.0
		Myristic acid	11.1
		Palmitic acid	9.5
		Stearic acid	10.3
		Oleic acid	15.7
		Linoleic acid	9.4
		Glycerol	44.0

[a] Levels were 25 mg. per 20 ml. of medium.

Trials 3 and 4. The results of trials 3 and 4 appear in table 2. In trial 3, additions of lauric, oleic, and stearic acids decreased the digestibility of cellulose, stearic and lauric acids decreasing it more than oleic acid.

In trial 4, cellulose digestion in the controls was similar between tests and the results were averaged. Butyric and valeric acids significantly ($P<0.01$) increased cellulose digestion. These effects were observed also by Bentley *et al.* (1954). Acetic and caproic acids had no effect at the level tested. The other fatty acids significantly ($P<0.01$) decreased cellulose digestion. Capric, lauric, myristic and palmitic acids had greater depressing effects than caprylic acid ($P<0.01$). Oleic acid again did not have the depressing effect of the other fatty acids with 12 to 18 carbons ($P<0.01$). Glycerol significantly ($P<0.05$) increased cellulose digestion.

It is apparent from the results that the fatty acids have a depressing effect upon ration digestibility as great as that observed with neutral fat. Nieman (1954), in summarizing his review of growth studies with pure strains of bacteria, concluded that the inhibitory effect of long chain fatty acids was best explained by the adsorption of the fatty acid to the cell, thereby altering the absorption and excretion powers of the cell. Camein and Dunn (1957) concluded that the inhibitory effects of saturated fatty acids of 12 to 20 carbons on the growth of lactic acid bacteria were antimetabolite. White *et al.* (1958) suggested that fat may have its effect by decreasing certain microbial metabolic activity. It has been demonstrated by Garton *et al.* (1958) that considerable lipolysis occurs in the rumen. It is suggested therefore that the fatty acids are responsible for the depressing effects observed with neutral fat and that they may also have an antimetabolic effect on the rumen microbial activity.

The difference observed in cellulose digestion between oleic acid and stearic acid *in vitro* and *in vivo* is possibly related to difference in melting point of the acids. In the studies *in vitro,* the stearic acid and oleic acid were melted onto the cellulose. In the lamb digestion study the stearic acid was mixed in the feed as a powder and oleic acid as a liquid. This difference in method of applying the fatty acids to the feed and cellulose could account for the differences noted. Tillman and Brethour (1958) reported that corn oil reduced the apparent and true digestibility of calcium and resulted in a decreased calcium retention. White *et al.* (1958) suggested that it may be possible to explain the calcium-fat relationship as due to the excretion of calcium soaps. Work on this problem is being continued in this laboratory.

Summary

Two digestibility studies were conducted with lambs to determine the effects of corn oil and fatty acids upon the digestibility of a ration containing 46% corn cobs. Studies were conducted *in vitro* to determine the effects of various fatty acids (C_2-C_{18}) and glycerol upon the digestion of cellulose by rumen microorganisms. In the digestibility studies involving

42 lambs, 5% corn oil, 5% of a mixture of fatty acids, 1% lauric acid, 5% stearic acid, and 5% oleic acid significantly decreased the digestibility of dry matter, organic matter and cellulose and significantly increased the digestibility of ether extract. All but lauric acid significantly decreased digestibility of ash. In studies conducted *in vitro,* butyric acid, valeric acid, and glycerol significantly increased cellulose digestion. Acetic and caproic acids had no effect at the level used. The saturated fatty acids from C_8 to C_{18} had a significant depressing effect upon cellulose digestion by rumen bacteria. Oleic and linoleic acids significantly decreased cellulose digestion.

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EFFECT OF AIR VELOCITY ON GAINS AND PHYSIOLOGICAL ADJUSTMENTS OF HEREFORD STEERS IN A HIGH TEMPERATURE ENVIRONMENT [1, 2]

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HEAT stress at temperatures over 80° F. reduces the productivity of cattle of most breeds. Mean monthly air temperatures near 90° F. are recorded each year from June through September in California's Imperial Valley. This area is a natural laboratory for studying the effects of a high-temperature environment on livestock production.

Reports have shown that increased air movement in a hot environment has a beneficial effect on the average daily gains of Hereford steers in wooden corrals (Ittner *et al.*, 1957). Wind has been beneficial to the dairy cow in a 95° F. environment (Brody, 1956). This paper reports further experiments conducted in the summers of 1957 and 1958 on the effect of air velocity on beef production in a hot climate.

Experimental

Trial I. The 1957 experiment was designed to study the effect of the period of fan operation on the weight gain of beef cattle during hot weather. Eight groups of three Hereford steers were placed in cable-fence pens 15 ft. × 48 ft. All pens were shaded by a galvanized steel shade 15 ft. wide which was painted white on top and provided 75 sq. ft. of shade per animal. The shade was 10 ft. high and oriented east and west. Buffer pens were located between each treatment group. The treatment, each with two replications, were control, the night fan (8:00 p.m. to 8:00 a.m.), the day fan (8:00 a.m. to 8:00 p.m.), and the 24-hour fan.

Three low-speed fans, 42 in. in diameter and rated at 17,000 cfm free air delivery, were mounted on the south side of the corral on the divisions between replicated pens. Air dry-bulb temperature, air velocity, and black-globe temperature were recorded by two micro-weather stations, one near a permanent weather station 600 feet west of the corrals and the other in one of the control pens. The animals were fed, free-choice, a ration of 50% concentrate and 50% roughage (table 1). The trial lasted 84 days, from June 26 to September 18. The animals were weighed in

[1] Cooperative project between the University of California and the U.S.D.A. The authors wish to acknowledge the assistance of Herdsmen, Phil Trask and Delbert Gaskin.
[2] Grateful acknowledgement is made to the late Nicholas R. Ittner under whose guidance the 1957 trial was conducted.
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TABLE 1. 1957 EXPERIMENT. WEIGHT CHANGES AND FEED CONSUMPTION [a]

Treatment	Control	Night fan	Day fan	24-hr. fan
Number of animals	6	6	6	6
Av. initial weight, lb.	646	638	643	651
Av. total gain, lb.	210	220	211	188
Av. daily gain, lb.	2.50	2.62	2.52	2.25 [b]
Av. daily ration, lb.				
Alfalfa hay	5.1	5.3	5.5	5.1
Alfalfa and barley hay	5.1	5.3	5.5	5.1
Barley	6.4	6.6	6.8	6.4
Molasses beet pulp	3.8	4.0	4.1	3.8
Total feed/100 lb. gain	816	811	868	912

[a] June 26–September 18, 1957=84 days.
[b] Lowered gain largely due to one animal.

the early morning, following 12 hours without feed or water. Table 1 records weight changes and feed consumption data. Table 2 summarizes air velocities and air temperatures recorded by the micro-weather stations.

An analysis of variance revealed no significant differences between treatments. This result, although different from the results of two previous years (Ittner *et al.*, 1957), is not necessarily contradictory. In fact, the 1957 test indicates that the greater natural air movement in a cable or wire pen over that in a wood pen, as used in previous tests, may be an important advantage for wire fences. This conclusion was previously suggested by Ittner *et al.* (1955). In the tests discussed by Ittner *et al.*

TABLE 2. AIR TEMPERATURE AND VELOCITY SUMMARY, 1957 AND 1958 EXPERIMENTAL PERIODS, IMPERIAL VALLEY FIELD STATION

	Air temperature (° F)			Air velocity (MPH)		
Location	Av. max.	Av. min.	Mean	Av. day	Av. night	Mean
	1957 (June 26 to September 18) [a]					
Weather station	107.4	74.0	90.6	4.0	2.7	3.4
Control pen	102.9	75.9	89.5	3.0	1.9	2.4
	1958 (July 3 to September 25) [b]					
Wire corrals:						
Control (no shade, no fan)	108.5	73.3	91.0	...	...	2.75
Shade	106.0	75.3	90.7	...	...	2.43
Fan	106.3	76.3	91.3	...	...	5.50
Shade and fan	103.1	75.9	90.2	...	...	5.99
Wood corrals:						
Shade	110.0	77.4	93.1	...	...	0.77

[a] Average maximum, minimum, and mean relative humidity for 1957 test period: 57, 18.6, and 35.0% respectively.
[b] Same for 1958 test period: 59, 27, and 37%.

(1957), fans were used to increase the air flow in the wood-fence pens from an average of 0.6 mph to 3.7 mph. The natural air flow in the wire-fence pens of the 1957 tests averaged 2.4 mph (table 2); fans increased this by only about 1 mph. Evidently the additional air did not benefit the animals. Under these circumstances, no differences due to length of operation of the fan could be distinguished.

Trial II. Tests in 1958 were designed for further study of the effects of mechanically increased air movement on the physiological reactions and productivity of Hereford steers in a high-temperature environment.

Six modified environments were created as follows:

	Total area	Shaded area
	(sq. ft. per animal)	
Wire corrals:		
Control—no shade, no fan	329	...
Shade—shade only	338	108
Fan—fan only	340	...
Shade/fan—shade and fan	340	108
Wood corrals:		
Shade—shade only	412	90
Shade/fan—shade and fan	442	85

The wooden corrals were identical to those described by Ittner *et al.* (1957). The fans were those described in the 1957 experiment; they were operated continuously during the entire trial from July 3 to September 23, 1958. Four micro-weather stations recorded dry-bulb air temperatures, air velocities, and black-globe temperatures throughout the experiment. Recorders were continuously in place at animal level in the control pen and the wooden corral shaded pen. The other two recorders were rotated among the three remaining pens in the wire corrals. Six Hereford steers were randomly assigned to each treatment. Weights were recorded after the animals went 12 hours, overnight, without feed or water. Table 3 shows the daily ration.

Physiological reactions in the four wire corrals were observed in four trained Hereford steers in the same weight range and on the same ration. A latin square design was used. Animal surface temperatures were measured with a touch thermocouple and with a radiometer. These instruments have been described by Kelly *et al.* (1949). Rectal temperatures were measured with a five-inch veterinary thermometer; heart rate and respiration rate were counted by the use of a stethoscope and stop watch. Daily water intake was measured as described by Ittner *et al.* (1951) for the four treatments in wire corrals.

Table 3 shows weight changes and feed consumption data. Analysis of variance did not indicate any significant increases in average daily gain that could have been contributed by increased air flow, although the difference between the unshaded check pen and the unshaded fan pen approached significance at the 5% level. In both the fanned and unfanned

TABLE 3. 1958 EXPERIMENT. WEIGHT CHANGES AND FEED CONSUMPTION [a]

Treatment	Wire corrals				Wood corrals	
	Control	Shade only	Fan only	Fan and shade	Shade only	Fan and shade
Number of animals	6	6	6	6	6	6
Av. initial weight, lb.	619	630	613	627	618	632
Av. total gain, lb.	137	191	155	181	168	171
Av. daily gain, lb.	1.63	2.28	1.85	2.15	2.00	2.04
Av. daily ration, lb.						
Alfalfa hay	7.8	9.3	8.4	8.9	8.0	8.9
Sudan hay	0.6	0.8	0.6	0.7	0.8	0.8
Concentrate mix [b]	7.8	9.3	8.4	8.9	8.0	8.9
Feed/100 lb. gain	994	851	940	869	840	912

[a] July 3–September 25, 1958=84 days.
[b] 3 parts barley, 1 part molasses beet pulp.

pen comparisons, shade produced significant increases in daily gain over that of unshaded groups.

Table 4 shows daily water intake for the four treatments in wire corrals. Animals in shaded pens consumed significantly less water per pound of dry matter eaten than animals in unshaded pens. Those in the shaded pen, with the fan, consumed significantly less water than those in the shade-only pen.

A twenty-four hour behavior study was conducted from noon, August 12, to noon, August 13, but this study did not indicate any essential differences in the eating habits of the animals in the six pens or bring to light any other peculiar differences in their behavior.

Table 5 summarizes the physiological measurements taken at two periods during the trial. These measurements were made during four-hour afternoon periods when air temperatures were at or near maximum.

Latin square analysis of the physiological data indicated that (1) heart rate was not affected by any treatment; (2) shade significantly reduced surface temperature, rectal temperature, and respiration rate; (3) fans reduced surface and rectal temperature as well as respiration rate when

TABLE 4. 1958 EXPERIMENT. DAILY WATER INTAKE PER ANIMAL

Treatment	Wire corrals			
	Control	Shade	Fan	Fan and shade
Water in feed (gal.)	0.14	0.16	0.14	0.15
Water consumed (gal.)	12.51	12.90	13.53	11.01
Total water intake (gal.)	12.65	13.06	13.67	11.16
Gal./lb. dry matter consumed	0.84	0.73	0.85	0.65

TABLE 5. 1958 EXPERIMENT. PHYSIOLOGICAL REACTIONS OF HEREFORD STEERS TO THE MODIFIED LOCAL ENVIRONMENT [a]

	Surface temp. (° F.) [b]		Rectal temp. (° F.) [c]		Resp. rate (/min.) [c]		Heart rate (/min.) [c]
Date:	9/4–5	9/25–26	9/4–5	9/25–26	9/4–5	9/25–26	9/25–26
Control	106.5	115.6	106.0	106.9	151	165	86
Shade	100.5	105.0	103.4	104.4	109	133	83
Fan	104.4	110.9	105.7	105.7	146	149	91
Shade and fan	99.9	103.6	103.3	104.2	102	128	87

[a] Av. maximum air temperature in control pen during measurements: August 4–5, 106.5° F.; August 25–26, 113.5° F. Average relative humidity: August 4–5, 53; August 25–26, 50.
[b] Average of 48 individual readings made at six locations on each animal.
[c] Average of eight individual determinations.

no shade was available; and, (4) fans did not significantly affect any of the physiological measurements when shade was available to the animals.

Discussion

The following equations show that air velocity is potentially a means of increasing heat loss, by either convection or evaporation (Bond *et al.*, 1958). They describe the rates of convective and evaporative heat exchange.

$$\text{Convection heat exchange: } q_e = CA_eV^n(t_{as} - t_{air})$$

$$\text{Evaporative heat transfer: } q_e = KA_eV^n(P_{as} - P_{air})$$

In these equations C and K are constants; A_e is effective surface area; V is air velocity; t is temperature; P is vapor pressure; and n is a velocity exponent. The subscript "as" indicates animal surface.

The convective heat-exchange equation indicates that, regardless of air velocity, no cooling by convection can occur unless the animal's surface temperature is greater than air temperature. The surface temperature of the unshaded steers (table 5) was generally higher than air temperature during the periods when the physiological measurements were taken, averaging 5° F. to 10° F. higher for the unfanned animals. The convection equation indicated that an increase in air velocity should increase the convective cooling in this case, as it evidently did since rectal temperature, surface temperature, and respiration rate of the fanned cattle were significantly reduced. On the other hand, at air temperatures higher than about 100° F., the average surface temperature of the shaded steers was lower than the air temperature. No benefits should be expected from convection cooling under these conditions. Since an increased air flow lowers an animal's surface temperature, it narrows the beneficial range of convective cooling; consequently, there is a limiting air temperature above which there is no cooling by convection. This fact evidently accounts for the lack of a significant difference in weight gain between the shaded fanned and unfanned pens.

Kibler and Brody (1950) showed that surface vaporization is a major route of heat loss in cattle at air temperatures over 75° F. The evaporative heat transfer equation indicated that increased air velocity should increase surface evaporative heat loss, independent of air temperature (except for the effect of air temperature on animal surface and air vapor pressures). The primary factor that limits the amount of evaporative cooling must surely be the rate at which moisture passes through the skin (a change in surface vapor pressure due to a supply of water), rather than the rate at which it is evaporated from the animal surface. This supposition is confirmed by the fact that in high temperature situations it is rarely possible to find evidence of moisture on the surface of cattle. Also, the fanned cattle consumed no more water (in one case significantly less, table 3) than the unfanned cattle. The data suggest the possibility of a limiting air velocity for evaporative cooling, in addition to the limiting air temperature for convection cooling already mentioned.

In the 1958 tests, the weight gains of the cattle in the wood-fence pens were not significantly different from those of cattle in comparable wire-fence pens. This result does not agree with the results of previous tests (Ittner *et al.*, 1957). A possible explanation may lie in the feeding. A larger percentage of concentrate was fed in 1958 than in previous tests; also, the ration was self-fed rather than hand-fed, as in previous tests. Fanned animals in the wood-fence pens averaged 0.32 lb. a day less gain than in the previous study whereas the control group averaged 0.42 lb. more than the previous controls.

Summary

Supplementing natural air movement with fans during two summers in the Imperial Valley of California (average daily temperatures were near 90° F.) indicated the following:

1. No significant increases in animal productivity could be attributed to increased air velocity when shade was available to animals in wire or cable corrals.
2. Fans significantly lowered rectal temperature, surface temperature, and respiration rate when no shade was available, and did not affect these parameters when the animals had shade.
3. Water intake per pound of dry matter consumed was lowered by shade and by the combination of shade and a fan.
4. Wire corrals provided a more comfortable summer environment than wooden corrals.

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EFFECT OF VARYING PROTEIN AND ENERGY INTAKES ON GROWTH AND CARCASS QUALITY OF SWINE

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CONFLICTING experimental evidence exists concerning the relative value of increasing the energy content of growing and finishing swine rations through the addition of graded levels of fat. Abernathy *et al.* (1958) reported that the addition of 5% or 10% stabilized prime beef tallow to swine rations resulted in significant increase in rate of gain but not in backfat thickness as measured by the live probe. Clawson and associates (1956) found little difference in rate or efficiency of gain attributable to protein: energy ratios. Likewise, Kropf *et al.* (1954) were unable to obtain a consistent increase in average daily gain from the addition of 10% or 15% ground waste beef fat to swine rations. Efficiency of feed utilization was improved by the fat additions, but no clear-cut effect of added fat upon dressing percentage or backfat thickness was noted. These workers reported that at the 10% or 15% level of substitution fat had 115% the value of corn.

Potter *et al.* (1956) found that at a constant protein level, growth rate in chicks consistently increased as the calorie:protein ratio increased up to a level of 1150 Calories of productive energy per pound. Chick growth rate and gain: feed ratio were apparently more closely associated with the productive energy level than with the calorie:protein ratio. Combs and Romoser (1955) demonstrated that as the energy content of chick rations is increased, protein level must also be increased to maintain the same rate of growth.

Objectives of the following experiments were (1) to test the effects on growth, feed efficiency and carcass quality of three levels of energy at each of three protein levels, and (2) to determine if the response from the various treatments differed with season (winter versus summer).

Experimental Procedure

Experimental group feeding trials were conducted in each of two seasons (winter and summer) in the same barn with crossbred pigs of similar origin. The barn was of concrete block construction and was without insulation. No provision was made for either heat in winter or artificial cooling in summer.

The pigs were raised on concrete, weaned at 8 weeks of age and assigned to the different regimes from outcome groups based on initial weights,

[1] Published with the approval of the Director of the Arkansas Agricultural Experiment Station.

sex and litters. Individual pigs were removed from the feeding pens when they attained a weight of 200 lb. The first two barrows to attain this weight in each lot in each season were slaughtered for carcass data.

In each of the two seasons the three levels of protein, 12%, 16%, and 20% were fed for the entire feeding trial; at each level of protein, energy levels were 950, 1050, and 1200 Calories (Fraps Productive Energy values) per pound.

Ground rice hulls, stabilized animal fat, and soybean oil meal were used to adjust the protein and calorie contents of the rations. Composition of the rations is presented in table 1. In order to keep the fat additions to a minimum solvent process (50% protein) soybean oil meal was used in the higher energy, higher protein rations. The productive energy values used as guides in formulating the rations were as reported by Fraps and revised by Titus (1955), namely, ground corn, 1110; 44% soybean oil meal, 727; 50% soybean oil meal, 790; and, stabilized animal fat, 2878 Calories, per pound. Rice hulls were calculated as having no productive energy for pigs. Unpublished work at the Arkansas Station indicates that the digestibility of ground rice hulls for swine is very low.

The rates of gain were statistically analyzed by analysis of variance (Snedecor, 1956).

Results and Discussion

Winter Trial. In the period from weaning to 75 lb., gains of pigs fed the 12% protein rations were depressed with increasing quantities of productive energy (table 2). This depression was not apparent for the entire trial. For the entire feeding trial, increasing levels of energy resulted in faster gains at the 20% level of protein. At the 12% and 16% level of protein the pigs fed the 1200 Calorie rations gained no faster than those fed the 950 Calorie rations.

Increasing levels of energy resulted in more efficient gains. The regression of feed required per pound of gain on level of productive energy fed was: $\hat{Y}=8.406-0.00464X$. The correlation between feed requirement and level of productive energy was —.97.

Summer Trial. For the entire feeding trial, increasing levels of energy resulted in faster gains at all levels of protein. The pigs fed the 16% protein-1200 Calorie ration gained 16.7% faster than those fed the 12% protein-1050 Calorie ration. During the winter trial this difference amounted to 3.7%.

At each protein level increasing increments of energy reduced the feed required per pound of gain. The regression of feed required per pound of gain on level of productive energy fed was: $\hat{Y}=6.827-0.0035X$. The correlation between these two variables was —.92.

Combined Trials. A summary of the analysis of rates of gain in both seasons is presented in table 3. There was a highly significant seasonal

TABLE 1. COMPOSITION OF RATIONS FED TO PIGS [a]

	12% Protein			16% Protein			20% Protein		
Calories productive energy per lb.	950	1050	1200	950	1050	1200	950	1050	1200
Ground yellow corn, lb.	78.00	89.25	81.00	71.75	80.75	69.05	65.00	70.00	57.65
Solv. process soybean meal (44%), lb.	11.00	9.00	.....	21.20	.....	.....	31.40	.....	.....
Solv. process soybean meal (50%), lb.	.....	.....	9.25	.....	17.00	19.20	.....	26.50	29.10
Ground rice hulls, lb.	9.25	.....	.....	5.30	.....	.....	1.85	.....	.....
Stabilized animal fat, lb.	.....	.....	8.00	....	0.50	10.00	.....	1.75	11.50
Actual gross energy content, Cal./gm.[b]	3.77	3.55	3.88	3.82	3.81	4.23	3.79	4.07	4.43
Estimated % T.D.N.	71	78	88	74	82	90	76	80	92
Calorie: protein ratios	79.2	87.5	100	59.4	65.6	75.0	47.5	52.5	60

[a] Each ration also contained 0.5% salt, 0.75% dicalcium phosphate, 0.5% ground limestone and 2200 I.U. vitamin A, 200 I.U. vitamin D_3, 2 mg. riboflavin, 5 mg. calcium pantothenate, 12.5 mg. niacin, 50 mg. choline chloride, 8 mcg. vitamin B_{12}, 10 mg. oxytetracycline per pound and 100 p.p.m. supplementary zinc.

[b] Average of two samples.

TABLE 2. RESPONSE OF PIGS TO RATIONS CONTAINING DIFFERENT LEVELS OF PROTEIN AND ENERGY

Calories productive energy per lb.	12% Protein			16% Protein			20% Protein		
	950	1050	1200	950	1050	1200	950	1050	1200
					Winter trial[a]				
Av. int. wt., lb.	43	44	44	43	43	43	43	42	44
Av. final wt., lb.	170	178	169	179	163	181	170	177	184
Av. daily gain, lb.	1.52	1.61	1.51	1.64	1.45	1.67	1.52	1.62	1.71
	±.071[b]	±.064	±.123	±.064	±.046	±.056	±.097	±.047	±.073
To 75 lb.	1.54	1.43	1.31	1.59	1.38	1.83	1.40	1.65	1.79
	±.086	±.083	±.231	±.063	±.082	±.088	±.121	±.036	±.084
75–125 lb.	1.49	1.65	1.53	1.60	1.46	1.57	1.48	1.56	1.64
	±.059	±.050	±.090	±.070	±.046	±.069	±.092	±.030	±.084
125–end	1.63	1.78	1.83	1.73	1.58	1.73	1.63	1.68	1.79
	±.133	±.084	±.137	±.051	±.058	±.064	±.126	±.075	±.076
Feed per lb. of gain, in.	4.12	3.58	3.06	4.07	3.44	2.80	3.89	3.43	2.71
Av. daily feed, lb.	6.26	5.76	4.62	6.67	4.99	4.68	5.91	5.56	4.63
					Summer trial[c]				
Av. int. wt., lb.	40	42	41	42	40	41	40	42	44
Av. final wt., lb.	188	198	194	190	191	202	192	193	201
Av. daily gain, lb.	1.62	1.68	1.74	1.79	1.82	1.96	1.78	1.80	1.95
	±.096	±.097	±.081	±.053	±.065	±.053	±.055	±.042	±.080
To 75 lb.	1.16	1.10	1.09	1.45	1.24	1.53	1.38	1.64	1.64
	±.118	±.098	±.109	±.028	±.036	±.111	±.060	±.029	±.087
75–125 lb.	1.71	1.80	2.02	1.90	2.10	2.08	1.73	1.72	1.90
	±.106	±.060	±.130	±.095	±.081	±.068	±.054	±.065	±.096
125–end	1.81	2.14	2.23	1.90	2.02	2.06	2.12	1.93	1.96
	±.114	±.055	±.103	±.060	±.075	±.113	±.026	±.073	±.041
Feed per lb. of gain, lb.	3.41	3.31	2.80	3.79	3.02	2.64	3.42	2.97	2.51
Av. daily feed, lb.	5.52	5.56	4.87	6.78	5.50	5.17	6.09	5.35	4.89

[a] Eight pigs per lot.
[b] Standard error of mean.
[c] Six pigs per lot.

effect ($P<.01$) on rate of gain. This difference in gain could not be separated from any difference between the two groups of pigs fed in the two seasons. At the Experiment Station weather station the average mean minimum temperatures during the three months of the winter trial were 36°, 26°, and 25° F., and the average mean maximum temperatures for the three months of the summer trial were 86°, 87°, and 88° F. The summer temperatures were probably nearer the optimum temperatures necessary for maximum swine gains.

TABLE 3. SUMMARY OF ANALYSIS OF VARIANCE OF RATES OF GAIN

Source of variance	Degrees of freedom	Mean squares			
		To 75 lb.	75–125	125–end	For entire test
Season	1	1.11**	3.37**	2.98**	1.19**
Rations	8	0.51**	0.07	0.11	0.08
Protein	2	1.00**	0.10	0.05	0.10
Linear component	1	1.83**	0.01	0.05	0.17
Quadratic component	1	0.16	0.19	0.05	0.03
Energy	2	0.22	0.16	0.18	0.14
950 vs. 1050	1	0.01	0.07	0.04	0.02
1050 vs. 1200	1	0.28	0.09	0.15	0.05
Protein v energy interaction	4	0.41**	0.02	0.11	0.05
Experimental error	8	0.06	0.10	0.05	0.04
Sampling error	108	0.06	0.04	0.05	0.04

** $P<.01$.

In the period to 75 lb. there was a highly significant effect of ration ($P<.01$) on gains. During this period the linear component of the protein effect was highly significant.

The effect of energy on gains was not significant in any of the periods. Pigs fed the 1050-Calorie rations did not gain significantly faster than those fed the 950-Calorie rations nor did the pigs fed the 1200-Calorie rations gain significantly faster than those fed the 1050-Calorie rations. During the initial period (40–75 lb.) there was a highly significant protein x energy interaction. In both winter and summer, the 1050-Calorie ration containing 16% protein produced slower gains from 40–75 lb. than the 950- or 1200-Calorie ration at the same level of protein. During the same period at the 12% level of protein, increases in energy level resulted in depressions in gain.

During the initial period of both feeding trials (40–75 lb.) the most rapid gains were obtained from the 1200-Calorie rations fed at either 16% or 20% protein. In the second period (75–125 lb.) the results from the winter and summer trials were somewhat conflicting as to which level of energy and protein produced the most rapid gain. During the final period

TABLE 4. INFLUENCE OF LEVEL OF ENERGY ON CARCASS QUALITY OF PIGS[a]

Calories productive energy per lb.	12% Protein			16% Protein			20% Protein		
	950	1050	1200	950	1050	1200	950	1050	1200
Av. slaughter wt., lb.[b]	192.5	200.5	203.2	196.5	191.8	206.5	203.2	198.5	205.0
Backfat thickness, in.[c]	1.42	1.52	1.68	1.46	1.37	1.62	1.46	1.46	1.64
Dressing percent[d]	74.3	75.7	73.8	75.4	74.8	77.8	74.9	76.2	76.1
Five primal cuts in carcass, %	59.6	57.5	59.2	61.4	63.0	61.0	59.0	61.2	61.9
Length, in.[e]	28.7	28.7	28.5	29.1	29.8	29.2	28.8	28.8	29.1

[a] All values are averages obtained from four barrows in each treatment.
[b] Weight after a 12-hr. shrink.
[c] Backfat thickness: Average of three measurements made at 1st rib, last rib, and last lumbar vertebra.
[d] Pigs dressed packer style.
[e] Length from 1st rib to aitch bone.

pigs fed the 12% protein-1200 Calorie ration made the most rapid gains in both trials. The 16% protein-1200 Calorie ration produced the most rapid gains for the entire summer trial and the 20% protein-1200 Calorie ration for the entire winter trial. The apparent relationship between the Calorie: protein ratio and rate of gain varied with the season and weight of the pigs. During the early part of the feeding trials the lower Calorie: protein ratios resulted in slightly more rapid gains. After the pigs weighed 125 lb. the rations with the highest Calorie: protein ratios produced the most rapid rates of gain. For the entire test, rations with Calorie: protein ratios of 49 to 75 produced gains which were slightly superior to the gains produced by rations with ratios of 79 to 100.

Carcass Results. The two fastest gaining barrows in each treatment were slaughtered in both trials. A summary of these data is presented in table 4. At each level of protein the highest level of energy (1200 Calories per pound) produced the fattest pigs as measured by average backfat thickness. At the 20% level of protein intake there was no difference in the backfat thickness between pigs fed the 950- and those fed the 1050-Calorie rations. At the 16% level, the 1050-Calorie ration produced leaner carcasses than the 950-Calorie ration. At the 12% level of protein there was apparently a positive relationship between energy level fed and backfat thickness.

Analysis of variance indicates that carcasses of pigs fed either 16% or 20% protein were longer ($P<.01$) and had a greater yield of primal cuts than those from the 12% protein group.

Summary

During two seasons corn-soybean oil meal type rations were self-fed to crossbred weanling pigs at three different protein levels, 12%, 16%, and 20% at each of three energy levels, 950, 1050, and 1200 Calories (Fraps Productive Energy values) per pound. Ground rice hulls and stabilized animal fat were used to adjust the energy to the desired levels. There was a highly significant seasonal effect on rate of gain, summer gains being the faster. All of the ration differences revealed by statistical analysis were during the period from weaning to 75 lb. During this period the linear component of the protein effect was highly significant. Analysis of the gains from both tests revealed no statistically significant difference between the gains of pigs fed the 950- and 1050-Calorie rations. During the period from 40 to 75 lb. there was a significant ($P<.01$) protein x energy interaction. Rations with Calorie:protein ratios of from 49 to 75 produced the fastest gains during the early part of the feeding trials (40–125 lb.). Later a Calorie:protein ratio of 100 resulted in the most rapid gains. Increasing levels of energy intake resulted in more efficient gains and lower daily feed intake. Carcasses from pigs fed the 1200-Calorie rations were fatter than those from pigs fed the 950- or 1050-Calorie

rations. Pigs fed the 16 or 20% protein rations produced longer carcasses ($P<.01$) with a greater yield of primal cuts as compared to pigs fed the 12% protein ration.

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PROBLEMS AND EVIDENCE IN SWINE BREEDING[1, 2]

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THIS talk will include first a brief survey of the state and outlook in swine breeding and then an outline and discussion of means for future progress. Some of you will think a part of it far-fetched. However, those of you who are concerned over swine improvement—and I assume that means all of you—will wish to reflect a little on even those portions.

Let's start with a quick look backward. What has happened in the last century that is pertinent to present-day swine breeding and our understanding of its problems? My list is as follows:

1. Formation of the standard pure breeds and the registry associations designed to promote the breeds and guard their integrity.
2. Mendel's work, its rediscovery and the following expansion of our knowledge in genetics. Obviously important has been the development of a body of population and quantitative genetic theory and the accumulation of now quite extensive information on genetic parameters and on responses to selection in various species.
3. Recognition of the value of crossbreeding in market hog production.
4. Renewed activity in breed formation (Minnesota No. 1, Montana No. 1, Beltsville No. 1, etc.) and the founding of the Inbred Livestock Registry Association.
5. A shift of emphasis to economic trait criteria of selection.
6. Objective analyses of selection and its effects in work of the Regional Swine Breeding Laboratory and other agencies.
7. Demonstration that backfat depth of the live hog can be measured easily and with reasonable accuracy.

Let's turn now to today's swine breeding and consider its structure and its prospects in that structure. There are two areas of activity, market hog production and seed stock production. I shall refer to the men who engage in seed stock production as the professional swine breeders. The welfare of our swine industry depends on the excellence, in performance and quality, of the market hog. This, in so far as it is genetic in origin, depends on (1) the genetic character of available seed stocks and (2) the way in which these seed stocks are employed in the breeding of market hogs. The bulk of market hogs in the U. S. are produced by crossbreeding and the majority of these by rotational crossbreeding or some reasonable facsimile. Seed stock required is in the form of boars. These for the most

[1] Read as an invitation paper at the 1958 annual meeting of the American Society of Animal Production.

[2] Miscellaneous Journal Paper No. 1015, Minnesota Agricultral Experiment Station.

part come from the pure breds, the old standard breeds or new breeds as the case may be. So long as this structure persists genetic improvement of our market hogs is dependent on genetic change in our pure breeds.

The salient features of breeding procedure in the purebreeds are outbreeding and selection aimed at phenotypic improvement of the purebreds themselves. A significant consequence of the outbreeding is that the genetic merit of every breed and every purebred herd depends on the effort and skill of at least several breeders. No single owner has full control over the efforts that bear on the genetic merit of even his own herd.

An attempt to assess the improvement in market hogs that is likely or possible poses two issues: (1) the improvement likely to be achieved in the purebreds themselves, and (2) how much of this will be reflected in animals produced by crossing the breeds. The answers differ with the character being considered.

Our present market is asking for a hog with less fat, more lean meat. The most logical first step toward such a hog appears to be through reduction in fatness. Estimates of the heritability and total variance of backfat thickness, accomplishments in Denmark, and preliminary reports on the effect of selection for reduced backfat by the U. S. Department of Agriculture, all indicate that rather rapid progress toward optimum fatness is possible. In addition there seem good reasons to believe that fatness in crossbreds will reflect quite faithfully the average fatness of their parent purebreds.

The evidence pertaining to performance traits (litter size, growth rate and the feed cost of growth) has a different flavor. Our estimates of heritability and total variance of these traits indicate that enough progress to be of considerable practical importance might result from selection. However, the proof of the pudding is in the eating, and the direct evidence has not fulfilled the promise of *a priori* possibilities. I shall refer only to the analysis by Dickerson *et al.* (1954) of selection and its effects in the inbred lines of the Regional Swine Breeding Laboratory. The crux of their findings with respect to litter size and growth were (1) that considerable selection had actually been practiced, and (2) that time trends, adjusted for inbreeding effects, gave no evidence that the selection had been effective. These findings deserve sober consideration; they represent the major portion of the good experimental work on swine selection in this country. However, they may, for reasons noted by the authors themselves, be misleading and there is of course other evidence, some a little more encouraging, none I think that justifies the belief that easy, rapid progress is possible.

Each of us comes away from the evidence he has seen with his own convictions. Mine are that some progress in the performance traits is possible and that continuing, strong selection may eventually bring sizeable total improvement in pure breeds.

Very briefly, my views of the present situation are:

1. In the present structure of swine breeding, genetic improvement will, at best, be very slow except in the case of backfat thickness and correlated carcass characters.
2. Selection for economic traits in our breeds is relatively weak. It cannot approach a maximum until appropriate measurement data are collected throughout at least a key segment of each breed.

What follows will deal first with four possible avenues to enhanced improvement of market hogs and, second, with potential change in the structure of professional swine breeding.

Evaluation of Breeds in Terms of Combining Ability and Renewed Attention to Crossing Systems

It is not reasonable to believe that all breeds or sets of breeds are equally good for use in crossing. But which are the best ones and how much better. We don't know, but why not find out. Can we be very certain that the magnitude of differences discovered will not be worth the effort—I don't think so. This would require an extensive testing program. But raising crossbred hogs is *not* an expensive activity—farmers make money that way. Beside the ordinary inputs of market hog production, it would take some special organization, some personnel for supervision and for data collection and processing, and some initial investment in facilities required. I have a feeling that such a program could be made very nearly, if not completely, self-supporting. It could be done on state or federal owned farms, or by contract arrangement with selected farmers.

Let's go a step further. Given a particular superior set of, say, three breeds, isn't it probable that one of the possible three-way crosses is better than the others and better than the three breed rotation cross. By a three-way cross I mean the mating of single-cross females with boars of a third breed. Commercial use of a three-way cross requires the farmer to buy replacement females or to maintain some purebred sows for production of the single-cross females required. In this age of increasing specialization, I suspect that many farmers would buy replacement females, if by so doing their market hogs were enough improved. If so, the issue boils down to economics; would the gain in market hog performance and quality offset the higher cost of female replacements resulting because single-cross females have purebred rather than crossbred dams. Perhaps net profit would be maximized by using a pair of breeds or lines in a criss-cross program for the production of the market man's brood sows which in turn would be bred to males of a particular third breed for the production of the bulk of his market hogs. Many farmers could handle the entire system, both types of crosses, on their own farms.

The evaluation of crossing systems would be an undertaking of some magnitude but far from an impossible task. The breed evaluation phase

of the proposal would be truly formidable by present standards. However, given the will to do the job, I believe a satisfactory sequential series of tests that would screen out tail-end breeds at successive stages could be devised. The task would still take more animals than we ordinarily allow ourselves to think about, quite a lot of time, and probably some unique approach for obtaining the initial support required.

Intensification of Selection in the Breeds

The problem of maximizing the effectiveness of selection for the improvement of a breed might, I think, be solved by the breed association concerned. The first requirement is collection of the necessary data. This is conceivably possible in the framework of testing stations of the sort established in the last few years but it would take many more of them. I'm very dubious that what is really necessary would ever get done that way.

If the mating structure of a breed were completely random, maximum selection would require performance testing of all animals in the breed. However, some herds contribute more than their share to the future germ plasm of a breed. These key herds are the ones where complete testing would mean most in terms of improvement of the whole population. This could be exaggerated to the point where exhaustive testing of all animals in a relatively small number of herds would provide the basis for extending near maximum effectiveness of selection throughout the breed.

What I have in mind probably has defects and doubtless can be improved. I offer it as a jumping-off place in considering the problem. Suppose all breeders were invited to institute a specified on-the-farm testing procedure in their herds with provision for adequate supervision and guidance. Only a minority would respond. However, if in addition to their testing programs, these men were required to use as breeding stock only elite animals from their own or other tested herds, the value of the testing program would be fully realized in these tested herds. If other breeders were then required to use boars obtained from the tested herds, or encouraged to do so by making it prerequisite to some superior designation for their own animals, the improvement of the tested herds could be extended through the breed.

One of the obstacles to effectiveness of selection in an entire breed is the environmental variation among farms. It seems to me that this would be largely circumvented if animals were always compared in terms of deviations from the mean of their own herd. This would discourage pampering as a device for attaining superior, but undeserved, ratings if the rules of the game required the same treatment for all animals within each herd.

There of course would be numerous operational details to be worked out that cannot be considered here. However, this scheme or a variant could in my opinion work to change present rather weak selection for perform-

ance to quite strong selection without requiring performance testing throughout a breed—a goal that would be very difficult to attain.

This is not a new idea. The advanced registry principle that it embodies has been proposed and considered in the past and is in use in swine breeding outside this country. However, the time now seems ripe for putting some such scheme in operation here. I believe that anyone who claims, or professes to believe, that adequate progress can be achieved within the present structure of swine breeding in the U. S. should be an active champion of this sort of thing.

Selection for Combining Ability

Selection for combining ability, as I am using the term, is aimed directly at improvement of a particular cross. In swine the simplest and probably most useful application is in selection among sire families. Males are used for production of both purebred and crossbred progenies and selection among purebred sire families is based on performance of their crossbred half-sibs. So long as our market hogs are crossbreds, the primary criterion of genetic value in the breeds should be performance of the crossbred offspring of purebreds rather than performance of the purebreds themselves. Then why not make crossbred performance the direct object of selection rather than an indirect object as it is now. The question hinges on the nature of the genetic mechanism. As many of you know, if overdominance is important, crossbred improvement, that is not attainable by ordinary selection, should be attainable through selection for combining ability. On the other hand, in the absence of overdominance, the same ends should be attainable by either system but may come faster by ordinary selection.

Overdominance is now accepted as a plausible, perhaps the most plausible, explanation for the apparent ineffectiveness of selection for performance traits. It appears likely that what is involved may be not so much overdominance at the level of individual traits as overdominance, resulting from negative genetic correlations, at the level of the desired complex of traits. However, either way, the result relative to selection is the same.

If we are so willing to concede the probable importance of overdominance and if progress then must come from selection for combining ability, why do we hesitate? Probably the most cogent reasons are (1) that not everyone is convinced that an impasse has *actually* been reached and (2) that selection for combining ability is a more complex process that requires a rather large breeding herd if its potential is to be fully realized. A program being initiated at Minnesota for improvement of a three-way cross by this procedure is scheduled to employ about 75 boars and 250 litters per year.

Two technical arguments against selection for combining ability have been advanced. One is that it will suffer from being a family selection system; family selection is known to be inefficient compared to individual selection unless heritability is very low. The facetious answer to this would

be that selection for combining ability could hardly be less effective than what we are doing. The non-facetious answer is that if negative genetic correlations are important, the effective genetic variance among crossbred sire families may be considerably *greater* than that within the breeds. The other objection is that as a result of past selection gene frequencies are likely to be very similar in different populations. If so, selection for combining ability would, at the outset, be favoring the same genotypes as conventional selection. Until chance events brought differential changes in the populations, progress could hardly be greater than by conventional selection. One answer to this is that if gene frequencies were *really* the same in all breeds, we would not get heterosis in crosses.

The logical and constructive thing will be to get about the collecting of pertinent information. Genetic variances among crossbred sire families can be estimated. These provide the same sort of basis for predicting progress from selection for combining ability that are obtained in the case of ordinary selection from estimates of additive genetic variance. Such estimates will become available in the course of experimental selection for combining ability and in advance of adequate testing of the selection system itself. In fact, some estimates of this kind must already be available from work at Oklahoma, Wisconsin, and the U. S. Department of Agriculture. If such estimates are encouraging, studies of selection for combining ability should certainly be continued. The estimates I have seen, from data on corn and chickens, have been encouraging.

Another kind of pertinent information is the regression of crossbred sire progenies on purebred sire performance. If this regression is low, selection for purebred performance will be proportionately ineffective for crossbred improvement and the potential of selection for combining ability should be fully explored.

The Potential of New Breeds

The critical issue here is whether the gene pool provided by any of the existing breeds is as extensive in terms of useful genes as can be obtained in new populations obtained by crossing existing breeds. Does each breed lack completely some of these that are present in one or more other breeds. One piece of undeniable evidence is the occurrence of heterosis. There could be no heterosis if there were no genetic difference between breeds. Another bit of evidence is supplied by the undoubted breed differences in average phenotype. Of particular interest are the known differences in fecundity. Litter size unlike some other traits is under constant natural selection in all breeds and the intensity of total selection for this trait cannot be much different in the different breeds. If the same genes are present in all breeds, one may ask why continued selection has not resulted in more nearly the same average litter size in all breeds.

Of course neither heterosis nor phenotypic difference is sufficient proof that qualitative gene differences exist. It may simply be that the various breeds, though possessing the same genes have approached what Sewall Wright has described as different adaptive peaks. In that event breed differences, that are unalterable by positive selection, would rest in gene frequency differences rather than actual gene differences. If this is the case, negative selection followed by positive selection could in theory transport a breed to a new and higher peak. Perhaps this possibility is worth some experimental attention.

The major argument for absence of breed variation in actual gene content is that the inbreeding involved in breed formation was so slight that more than trivial differences in genes possessed are unlikely. Another way of saying this is that the sample of animals from which each breed was founded was large enough to make it improbable that any useful gene of the species was not possessed by one or more member of the sample. The weight of the argument depends on at least three things about which we lack decisive information; the genetic homogeneity of the specie in the pre-breed days, the amount of inbreeding that was actually involved, and the frequencies then of the now useful genes. A point to be remembered relative to gene frequencies is that the now useful genes may not all have been favored by selection in the pre-breed days.

Besides the question of gene content of the animals on which the breeds were founded, we must consider the possibility of differentiation through mutation since that time. Favorable as well as unfavorable mutants occur, otherwise progressive evolution would not have occurred. Mutations are rare events; within the span of 60 to 100 years a favorable mutant that occurred and persisted in one breed could hardly have been expected to both occur and persist in all other breeds. Can we be certain that original divergence in gene content has not been significantly increased by mutation.

When I attempt to take an objective view I come up with something like this. Breeds may differ by significant amounts in gene content. If they do, maximum potential is not provided by selection within these existing closed populations. Moreover, even if breed differences are not a matter of gene content but only due to near attainment of different adaptive peaks, crossing breeds to provide new populations in which to select could be useful. A new population could be far enough from any old peak to be carried by selection to an entirely new and possibly higher peak.

What is needed are critical experiments designed to get at the basic issue. One approach that should prove useful is simultaneous selection in two breeds and in a third population formed by crossing them. Some work of this kind has been initiated (e.g. at Nebraska). It should be encouraged and watched with great interest.

To this point four subjects have been discussed independently. Some practical interrelations should now be noted. Selection for combining

ability and the nature of genetic differences between breeds require research attention. On the other hand the evaluation of breeds in terms of value for crossing and the intensification of selection in our breeds merit immediate action programs. If one were to come before the other it should be breed evaluation. In the first place, the elimination of inferior or unnecessary breeds should be accomplished as soon as possible to minimize the total effort to be expended in intra-breed selection. If the proposal for intensified selection is to be put in effect it should be done with breeds that have a deserving place in market hog production. Second, there is a limit to the number of breeds that can effectively be supported by the industry. If new ones are to be formed, some present breeds must be eliminated to make way for them. Breed development without breed evaluation would be an aimless activity. Finally, both combining relationships of present breeds and basic information on genetic differences between breeds will be pertinent to choice of foundation populations when and if practical programs of selection for combining ability are initiated.

Turning to another but not unrelated matter, it is an interesting fact that in an era of rapid change there has been almost no change in the nature of our professional swine breeding enterprises. This has not been true in some closely related areas. Corn and other sorts of plant breeding, and more recently poultry breeding, have been almost completely taken over by large business organizations. These organizations are highly competitive and as a matter of good business are engaging highly trained personnel to bring all our scientific knowledge to bear in improvement of the seed stocks they sell. Large enterprises based on sufficient initial capital would have several advantages in swine breeding. They could produce animals of enough breeds or lines to offer their patrons the whole variety of seed stock required for a sound crossing program. Their breeding herds could be large enough to allow their selection programs to be entirely self-contained and hence entirely at the disposal of one owner. Size of operation would be large enough to allow efficient exploitation for combining ability and to allow establishment of any sort of new population judged to be advantageous. Finally such an organization could afford completely qualified personnel and an effective advertising and service program for promoting its products.

You are aware that the beginnings of large enterprise in swine breeding have been made. Whether such operations will become dominant will, I should think, be affected by the following:

1. Whether selection for combining ability turns out to be a superior procedure in swine breeding.
2. The improvement potential inherent in establishment of new populations from crosses of existing ones.
3. Whether the volume of potential seed stock sales is sufficient to stimulate the development of efficient large scale enterprises. Sale possibilities would be greatly enhanced by general adoption of cross-

ing systems such that a considerable portion of replacement females as well as boars begin to be purchased by the market hog man.

4. How quickly and effectively our present breeders go about the things that they can do to improve our market hog. These include encouragement of programs for evaluation of breeds at the crossbred level, a willingness to drop breeds that do not meet the test and to accept and promote new breeds that do, and adoption of well chosen programs that will really maximize selection for economic traits in the breeds worthy of such effort.

It has been said that the world will beat a path to the door of the man who creates a better mousetrap. I suppose we could substitute market hog for mousetrap.

To summarize, I have suggested that within the present structure of swine breeding, progress can only be slow except in proportion of fat and related carcass traits. To maximize this progress, greatly intensified selection in the breeds is required. A very rough outline of how this might be accomplished has been provided.

With no intent to minimize the importance of capitalizing on all improvement that is potential in the present framework I have suggested three other possibilities for acceleration of progress: selection for combining ability, continued attention to the potential of new breed formation, and experimental eavluation of crossing systems and of the crossing value of our breeds. The most immediate need with respect to the first two is research. The third, to be effective, calls for action.

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THE REACTION OF THREE KINDS OF SINGLE-CROSS PIGS TO THREE LEVELS OF FEED INTAKE.[1] I. FEED LOT PERFORMANCE

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FEED lot performance in swine is influenced by type of ration, level of feeding and genetic constitution of the animals. Ellis and Zeller (1934), Crampton (1937), and Winters *et al.* (1949) reported that pigs on a restricted level of feeding utilized feed more efficiently than self-fed pigs though their daily rates of gain were not as great. Weaver and Bogart (1944) and Gregory and Dickerson (1952) reported differences between breeding groups in comparative response to different feeding treatments. Differential behavior between genotypes in different environments has obvious implications to animal breeding. This report will cover feed lot performance in an experiment designed to investigate the magnitude of genotype-environment interaction in swine.

Experimental Procedure

Three kinds of crossbred pigs (1956 fall-farrowed) and three feeding treatments were compared in a factorial experiment. The experiment was conducted in two replications with a total of 180 pigs; 10 in each of 18 lots.

The three kinds of pigs were all farrowed by Minnesota No. 1 sows but sired by boars of different breeding. The crosses were: (1) Minnesota No. 2 $\times$ Minnesota No. 1; (2) Minnesota No. 3 $\times$ Minnesota No. 1; and, (3) Minnesota No. 2A $\times$ Minnesota No. 1. The Minnesota 2A sires were from the F_1 cross of a Minnesota inbred line of Poland Chinas with Yorkshire boars from Prince Edward Island, Canada. The Minnesota No. 1 and Minnesota No. 2 lines were described by Winters *et al.* (1948) and the Minnesota No. 3 line by Sumption (1957). The composition of base rations employed is given in table 1.

Treatments were as follows:

(1) Formula A was full-fed until the pigs weighed approximately 100 lb. After this, Formula B was full-fed until the pigs reached approximately 200 lb. live weight.

(2) Formula A and B were fed over the same weight ranges as treatment 1. The animals were hand-fed twice daily to restrict daily intake to 85% of consumption by pigs on treatment 1. Amounts of

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feed offered were based on daily intake of full-fed pigs in two previous years (Cole, 1956) and are listed in table 2.

(3) Formulas A and B were modified by adding 20 parts by weight of 15-month-old ground grass and alfalfa hay to 80 parts of base ration. Formula A (modified) was full-fed to about 100 lb. live weight, then Formula B (modified) was full-fed until the pigs reached 200 lb.

There were five gilts and five barrows in all but three of the 18 pens. Two pens had three gilts and seven barrows; one had four gilts and six barrows. All pens were in one barn with the temperature controlled

TABLE 1. BASAL FEED MIXTURES FED IN THIS EXPERIMENT

Ingredient	Formula A, lb.	Formula B, lb.
Ground yellow corn	620	640
Wheat red dog middlings	200	...
Solvent soybean oil meal	35	50
Ground oats	...	200
Tankage	40	30
Dried skim milk	90	60
Steamed bone meal	10	15
Salt, trace mineralized	5	5
Aurofac[a]	5.6	5.6
Dried irradiated yeast[b]	0.1	0.1

[a] American Cyanamid Company feed supplement guaranteed to contain 1.8 mg. vitamin B_{12} plus 1.8 gm. Aureomycin activity per lb.
[b] 9000 I.U. of vitamin D per gm.

TABLE 2. DAILY FEED ALLOWANCES FOR PIGS ON TREATMENT 2

Weeks on experiment	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pounds feed per pig per day	3.01	3.34	4.3	4.7	5.3	5.3	6.0	6.3	6.8	7.2	7.5	7.5	7.5	7.5

TABLE 3. AVERAGE PEN WEIGHTS AND AGES OF PIGS BY REPLICATES, BREEDING, AND TREATMENT AT START OF EXPERIMENT

Treatment	Replicate	Initial weight (pounds) of cross				Initial age (days) of cross			
		2x1	3x1	2Ax1	Av.	2x1	3x1	2Ax1	Av.
1	1	54.5	55.8	46.2		60.3	59.4	57.0	
	2	54.3	55.9	46.2	52.1	59.7	59.2	56.7	58.7
2	1	53.7	58.2	52.0		59.4	61.3	58.6	
	2	53.6	58.1	52.1	54.6	59.4	61.6	58.0	59.7
3	1	52.6	47.8	50.0		56.0	53.3	56.0	
	2	52.6	48.0	50.0	50.2	55.8	53.1	56.0	55.0
	Av.	53.6	54.9	49.5		58.4	57.9	57.1	

TABLE 4. MEANS FOR FEED LOT PERFORMANCE BY TREATMENT-BREEDING GROUPS

Treatment	Breeding			
	2x1	3x1	2Ax1	Av.
		Av. daily gain, lb.		
1	1.91	2.04	2.02	1.99
2	1.67	1.61	1.66	1.65
3	1.71	1.66	1.68	1.65
Av.	1.76	1.77	1.79	1.77
		Age at 200 lb., days		
1	137.5	131.3	134.4	134.4
2	147.5	150.4	148.6	148.8
3	141.8	146.5	146.2	144.8
Av.	141.6	142.7	143.1	142.7
		Feed per 100 lb. gain, lb.[a]		
1	380	396	370	382
2	332	350	342	341
3	350	373	344	356
Av.	354	373	352	360

[a] Concentrate only in the case of treatment 3.

between 50° and 54° F. Table 3 lists average initial weights and ages by pens.

Data collected on feed lot performance were initial and final weight and age of each pig, and feed consumption by pens. From these data, rate of gain and age at 200 lb. were determined for each pig, and feed per 100 lb. gain and feed consumed per pig per day were determined for each pen.

Results and Discussion

Table 4 lists average results for the treatment-breeding groups.

An analysis of variance was computed for each measurement to test

TABLE 5. MEAN SQUARES FOR DAILY RATE OF GAIN, AGE AT 200 LB. AND FEED PER 100 LB. GAIN

Variation due to	D.F.	Daily rate of gain	Age at 200 lb.	Feed per 100 lb. gain
Reps.	1	0.0002	3.04	117
Treatment	2	.2112**	337.52**	2512**
Breeding	2	.0012	1.30	785**
B x T	4	.0054**	17.30**	80
Error	8	.0006	0.87	24
Total	17			

** Significant at 1% level of probability.

significance of breeding and treatment effects and the interaction between breeding and treatment. Table 5 gives the mean squares for rate of gain, age at 200 lb. and feed per 100 lb. gain. The pen means were employed in the analysis.

Breeding $\times$ treatment interactions were significant at P=.01 for rate of gain and age at 200 lb., while breeding had a significant effect at P=.01 for only feed per 100 lb. gain. Treatment had a significant effect at P=.01 in all the three characteristics measured.

The significant B $\times$ T interaction is of great interest. In order to check on the possibility that the apparent interaction resulted from initial weight differences, covariance analyses were performed to allow computation of correlations between initial weight and rate of gain and between initial weight and age at 200 lb. for the B $\times$ T line of the analysis. These were found to be both insignificant and very small (−.13 and −.11, respectively). Hence, there is no reason why the significant B $\times$ T interaction cannot be taken at face value.

These significant B $\times$ T interactions were due to the fact that the different breeding groups were not consistent in their response to the three feeding treatments. A similar interaction could occur with other factors of environment, such as temperature or kind of feed.

The 3 $\times$ 1 breeding was the greatest in average daily gain and least in age at 200 lb. under full-feeding, but their daily gain was the lowest and their age at 200 lb. was greatest of the three breeding groups under the other two feeding treatments. The 2 $\times$ 1 breeding had the greatest daily gain and was the least in age at 200 lb. when subjected to the 85% restricted feeding or when fed a feed containing 20% ground hay.

The evidence for B $\times$ T interaction indicates that the comparative performance of two or more types of breeding in a particular trial should not be depended upon as final evidence of the relative values of these different breeds or crosses. Instead, such conclusions can be reached with reasonable certainty only after some repetition of the comparison in different environmental situations.

Summary

Heredity and environment interactions were studied in regard to feed lot performance by subjecting three kinds of crossbred pigs to three feeding treatments in a factorial experiment. The experiment was conducted in two replications with a total of 180 pigs, 10 in each of 18 pens. The crossbred pigs were sired by the Minnesota No. 2, Minnesota No. 3 and Minnesota No. 2A boars and out of Minnesota No. 1 dams. The treatments were full-feeding, 85% restricted feeding, and the self-feeding of a feed mixture containing 20% grass and alfalfa meal and 80% concentrates. The feed lot performance characteristics studied were average daily gain, age at 200 lb., and feed per 100 lb. gain.

TABLE 4. MEANS FOR FEED LOT PERFORMANCE BY TREATMENT-BREEDING GROUPS

Treatment	Breeding			
	2x1	3x1	2Ax1	Av.
	Av. daily gain, lb.			
1	1.91	2.04	2.02	1.99
2	1.67	1.61	1.66	1.65
3	1.71	1.66	1.68	1.65
Av.	1.76	1.77	1.79	1.77
	Age at 200 lb., days			
1	137.5	131.3	134.4	134.4
2	147.5	150.4	148.6	148.8
3	141.8	146.5	146.2	144.8
Av.	141.6	142.7	143.1	142.7
	Feed per 100 lb. gain, lb.[a]			
1	380	396	370	382
2	332	350	342	341
3	350	373	344	356
Av.	354	373	352	360

[a] Concentrate only in the case of treatment 3.

between 50° and 54° F. Table 3 lists average initial weights and ages by pens.

Data collected on feed lot performance were initial and final weight and age of each pig, and feed consumption by pens. From these data, rate of gain and age at 200 lb. were determined for each pig, and feed per 100 lb. gain and feed consumed per pig per day were determined for each pen.

Results and Discussion

Table 4 lists average results for the treatment-breeding groups.

An analysis of variance was computed for each measurement to test

TABLE 5. MEAN SQUARES FOR DAILY RATE OF GAIN, AGE AT 200 LB. AND FEED PER 100 LB. GAIN

Variation due to	D.F.	Daily rate of gain	Age at 200 lb.	Feed per 100 lb. gain
Reps.	1	0.0002	3.04	117
Treatment	2	.2112**	337.52**	2512**
Breeding	2	.0012	1.30	785**
B x T	4	.0054**	17.30**	80
Error	8	.0006	0.87	24
Total	17			

** Significant at 1% level of probability.

significance of breeding and treatment effects and the interaction between breeding and treatment. Table 5 gives the mean squares for rate of gain, age at 200 lb. and feed per 100 lb. gain. The pen means were employed in the analysis.

Breeding × treatment interactions were significant at P=.01 for rate of gain and age at 200 lb., while breeding had a significant effect at P=.01 for only feed per 100 lb. gain. Treatment had a significant effect at P=.01 in all the three characteristics measured.

The significant B × T interaction is of great interest. In order to check on the possibility that the apparent interaction resulted from initial weight differences, covariance analyses were performed to allow computation of correlations between initial weight and rate of gain and between initial weight and age at 200 lb. for the B × T line of the analysis. These were found to be both insignificant and very small (−.13 and −.11, respectively). Hence, there is no reason why the significant B × T interaction cannot be taken at face value.

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The evidence for B × T interaction indicates that the comparative performance of two or more types of breeding in a particular trial should not be depended upon as final evidence of the relative values of these different breeds or crosses. Instead, such conclusions can be reached with reasonable certainty only after some repetition of the comparison in different environmental situations.

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Significant breeding × treatment interactions were found in average daily gains and in age at 200 lb. live weight.

Treatment mean squares were all significant at P=.01 for the three feed lot characteristics—daily rate of gain, age at 200 lbs. and feed per 100 lb. gain. Breeding groups mean squares differed significantly at P=.01 only for feed per 100 lb. gain and were non-significant in the case of daily gain and age at 200 lb.

The significant B × T interaction mean squares for daily rate of gain and age at 200 lb. indicate that the relative values of the genetic constitutions of the three different kinds of crosses used in this experiment varied with feeding treatment.

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RELATIONSHIP OF LOIN EYE AREA, SEPARABLE LEAN OF VARIOUS BEEF CUTS AND CARCASS MEASUREMENTS TO TOTAL CARCASS LEAN IN BEEF [1]

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PRESENTLY much emphasis is given to the meat-type steer and to its identification, alive and in the carcass. In the past, area or the "shape index" of the *Longissimus dorsi* muscle has been extensively used by various research workers and breed improvement programs as an index of total muscling of a particular carcass. Palsson (1939) reported that the degree of muscle development could be estimated best by observing the cross-sectional area at the last rib, since this area is the last to reach its full development as explained by the body growth gradient theory (Hammond 1932, McMeekan 1941, Wallace 1948, and Palsson and Verges 1952). Branaman (1940), working with lamb carcasses, reported the area of loin eye to be a fairly good index of total carcass lean. Hirzel (1939), Palsson (1939) and McMeekan (1941) have used the depth, length, and "shape index" (length/depth $\times$ 100) of the loin eye in evaluating the amount of muscling in pigs and sheep. Palsson (1939) reported correlation coefficients from sheep data of 0.77 in lambs and 0.81 in yearlings between carcass lean and the depth plus the length of the loin eye. Working with 200-lb. pigs, McMeekan (1941) reported a correlation of 0.84 between the same factors. Since the amount of muscle will be related to the linear as well as the cross-sectional area, Palsson (1939) and McMeekan (1941) obtained a better estimate of total carcass lean, when carcass length was combined with the depth and length of the loin eye.

Kline and Hazel (1955) have reported the positional variability of the loin eye area in pork carcasses. Data on cut out and chemical analyses of pork carcasses suggest that loin eye area is not highly related to total muscling of the entire carcass (Kline and Hazel 1955, and Price *et al.*, 1957).

Research data depicting the relationship between area of the loin eye and total carcass lean in beef are lacking in the literature. This study was undertaken to determine the validity of using the loin eye area, the lean

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content of a particular beef cut, or various other carcass measurements to predict total carcass lean.

Experimental Procedure

Data from 3 years of beef carcass investigations were analyzed, which included 81 steers, 9 heifers and 9 cows, representing the U.S.D.A. grades of choice (15), good (29), standard (38), commercial (9), and utility (8). Sixty-three of the above steers came from a type and breed study that included Angus, Hereford, Brahman, Brahman-British crosses, and dairy steers in which time of slaughter was determined by weight or age (900 lb. or 20 mos.). The remaining carcasses were purchased from a packer according to weight, (500 lb.) grade, and sex. Almost all types of carcasses were represented, ranging from the short-bodied compact beef type, to the longer-bodied and more angular dairy type steer. Measurements as described by Naumann (1951), were made on each carcass following slaughtering and chilling. An additional measurement, depth of flank, was taken from the extreme dorsal and ventral edges of the exposed surface when the sirloin was cut from the round. The left side of each carcass was cut into wholesale cuts as prescribed by Wellington (1953) after which a physical separation of lean, fat, and bone was made of each cut. Absolute values were used rather than percentages. Weights and measurements were taken to the nearest 0.1 lb or 0.1 in.

Simple and multilinear correlation coefficients, regressions, and standard partial regression coefficients were employed to analyze the data (Snedecor 1946). All calculations were made on a within year basis.

Results and Discussion

Loin Eye Area. The simple correlation coefficients between loin eye area and separable carcass lean and separable lean of the various wholesale cuts of beef are listed in table 1. Although all relationships were found to be highly significant, only 5 to 30% of the variation in separable lean of either the carcass or of a particular wholesale cut was associated with the loin eye area. The highest relationship existed between separable lean of the 9–10–11 rib section and loin eye area ($r=0.55$). This would be expected since the eye muscle makes up a good portion of the total lean from this cut. Area of loin eye was found to be associated with only 18% of the variation in separable carcass lean. Area of the loin eye was directly related to carcass weight, accounting for 27% of the existing variance in carcass weight.

The correlation coefficients between weight of the carcass, separable carcass lean and the separable lean of the various wholesale cuts are also listed in table 1. In all instances, the relationships were higher between separable lean of the carcass or of a particular cut and carcass weight than between these same items and the area of loin eye. This would be expected since the

separable lean of either the carcass or a particular cut is a part of the whole, or in this case, part of the carcass.

Standard partial regression coefficients were calculated for the regression of separable carcass lean (X_o) and the regression of lean in various cuts (X_i) on loin eye area (X_1) and carcass weight (X_2), (table 1, $b_{i1 \cdot 2}$ and $b_{i2 \cdot 1}$, respectively). With carcass weight held constant, standard partial regressions of separable lean of the whole carcass and of various cuts on loin eye area ($b_{i1 \cdot 2}$) were generally much smaller than were the simple

TABLE 1. SIMPLE, MULTIPLE CORRELATION AND STANDARD PARTIAL REGRESSION COEFFICIENTS OF SEPARABLE LEAN OF THE CARCASS AND VARIOUS BEEF CUTS WITH LOIN EYE AREA AND CARCASS WEIGHT

	r		b		R
X_i	Loin eye area (X_1) with	Carcass weight (X_2) with	$b_{i1 \cdot 2}$[a]	$b_{i2 \cdot 1}$[c]	X_i on X_1 and X_2
Separable carcass lean X_o	0.43**	0.77**	0.04	0.75	0.77
Separable round lean	.40**	.68**	0.06	.65	.68
Separable chuck lean	.37**	.70**	0.00	.70	.71
Separable foreshank lean	.33**	.57**	0.05	.55	.57
Separable sirloin lean	.22**	.54**	—.08	.58	.54
Separable shortloin lean	.42**	.59**	0.16	.51	.61
Separable rib lean	.44**	.60**	0.18	.51	.62
Separable 9-10-11 rib lean	.55**	.57**	0.35	.39	.64
Carcass weight	.52**	...	....	...	...
Separable carcass fat (X_3)	.33**	.59**	....	...	...

[a] Standard partial regression coefficient of X_i on loin eye area with carcass weight held constant.
[c] Standard partial regression coefficient of X_i on carcass weight with loin eye area held constant.
* Denotes significance at P=.05.
** Denotes significance at P=.01.

correlations between the same variables. On the other hand, with loin eye constant, standard partial regressions of these variables on weight ($b_{i2 \cdot 1}$) were quite similar to their respective simple correlations. These data show that carcass weight was more useful in predicting lean in the carcass and in various cuts than loin eye area. The multiple correlation coefficients, when combining loin eye area and carcass weight, failed significantly to improve estimates over those obtained with carcass weight alone (table 1.).

Separable carcass fat was related to carcass weight (r=0.59) and to a lesser degree to loin eye area (r=0.33), but showed small and usually negative values (r=0 to —.14) with lean of whole carcass and the different cuts. The multilinear correlation coefficients involving the weight of the separable fat were of about the same magnitude as those previously discussed when carcass weight was used.

Separable Lean of Various Beef Cuts. Inasmuch as the relationship of loin eye to carcass leanness was quite low, (accounting for 19% of the

variation), the separable lean of different wholesale cuts was investigated to see if in one or more of them it would be more useful than loin eye area as an estimator of carcass lean. The simple correlations between separable lean of the carcass and separable lean of seven beef cuts (table 2) ranged from 0.74 to 0.95. The separable lean of the round, chuck, and foreshank were associated with 90, 87, and 66% of the variation in total separable lean of the carcass, respectively. The validity of using the round or foreshank as an index of carcass leanness seems quite plausible due to their high predictive value, ultimate use, and relative ease of separation.

TABLE 2. SIMPLE, MULTIPLE CORRELATION AND STANDARD PARTIAL REGRESSION COEFFICIENTS OF SEPARABLE LEAN OF VARIOUS CUTS OF BEEF WITH SEPARABLE CARCASS LEAN AND CARCASS WEIGHT

	r		b		R
X_1	Separable carcass lean (X_0) with	Carcass weight (X_2) with	$b_{01 \cdot 2}$[a]	$b_{02 \cdot 1}$[c]	X_0 on X_2 and X_1
Separable round lean	0.95**	0.68**	0.80	0.23	0.97**
Separable chuck lean	0.93**	.70**	.76	.23	.94**
Separable foreshank lean	0.81**	.57**	.55	.46	.89**
Separable sirloin lean	0.80**	.54**	.55	.47	.90**
Separable shortloin lean	0.75**	.59**	.46	.50	.85**
Separable rib lean	0.79**	.60**	.52	.46	.87**
Separable 9-10-11 rib lean	0.74**	.57**	.44	.52	.85**
Carcass weight	0.77**	...	...	...	...
Separable carcass fat	—.05	.59**	...	...	...

[a] Standard partial regression coefficient of separable carcass lean on X_1 with carcass weight held constant.

[c] Standard partial regression coefficient of separable carcass lean on carcass weight, when X_1 is held constant.

** Denotes significance at P=.01.

The economic value of the foreshank (used for such an index) would be relatively unaffected since this cut usually goes into ground beef products. The round in some cases is broken into ham sets, from which boneless steaks and roasts are fabricated. A physical separation of the round would fit quite well into such a fabricating program, with little monetary loss. Furthermore, the separable lean of any one of the remaining beef cuts listed in table 2 was a better predictor of total carcass leanness or muscling than was the loin eye area.

Multiple regressions combining the lean in each of the seven cuts with carcass weight for estimates of total carcass lean were calculated. The standard partial regression coefficients ($b_{01 \cdot 2}$ and $b_{02 \cdot 1}$) are listed in table 2. In all cases, the standard partial regressions with weight constant ($b_{01 \cdot 2}$) were smaller than their respective simple correlation coefficients, while each multiple correlation coefficient showed a marked increase over the simple correlation between total carcass lean and carcass weight. Total

TABLE 3. SIMPLE AND MULTIPLE CORRELATION AND STANDARD PARTIAL REGRESSION COEFFICIENTS OF SEPARABLE LEAN OF CARCASS AND VARIOUS BEEF CUTS WITH LOIN EYE AREA, ON A WITHIN AND AMONG BREED BASIS [a]

	r				b				R	
	Loin eye area (X_1)		Carcass weight (X_2)		Within year, breed ignored		Within year and breed		X_1 on X_2 and X_3	
X_3	Within year	Within year and breed	Within year	Within year and breed	$b_{13.2}$ [c]	$b_{12.3}$ [d]	$b_{13.2}$ [c]	$b_{12.3}$ [d]	Within year	Within year and breed
Carcass separable lean (X_0)	0.57**	0.28*	0.83**	0.45**	0.08	0.78	0.20	0.41	0.83	0.49
Separable round lean	.54**	.33**	.75**	.39**	.11	.68	.27	.34	.75	.47
Separable chuck lean	.50**	.29*	.77**	.43**	.02	.75	.22	.39	.77	.48
Separable foreshank lean	.39**	.23	.61**	.30*	.01	.60	.18	.27	.61	.35
Separable sirloin lean	.40**	.21	.61**	.34**	.03	.59	.15	.31	.61	.37
Separable shortloin lean	.44**	.26*	.66**	.32*	.07	.61	.20	.28	.66	.38
Separable rib lean	.52**	.39**	.67**	.34**	.16	.57	.34	.28	.68	.48
Separable 9-10-11 rib lean	.62**	.40**	.70**	.35**	.30	.51	.35	.28	.74	.49
Carcass weight	.63**	.19	...	...	...	...	...	...	...	...

[a] Includes data on 63 steers of known heredity.
[c] Standard partial regression coefficient of X_1 on loin eye area, when carcass weight is held constant.
[d] Standard partial regression coefficient of X_1 on carcass weight, when loin eye area is held constant.
* Denotes significance P=.05.
** Denotes significance P=.01.

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	r				b				R	
	Separable carcass lean (X_o)		Carcass weight (X_2)		Within year, breed ignored		Within year and breed		X_o on X_2 and X_1	
X_1	Within year	Within year and breed	Within year	Within year and breed	$b_{o1.2}$ [c]	$b_{o2.1}$ [d]	$b_{o1.2}$ [c]	$b_{o2.1}$ [d]	Within year	Within year and breed
Separable round lean	0.97**	0.95**	0.75**	0.39**	0.79	0.23	0.91	0.09	0.98**	0.95**
Separable chuck lean	.93**	.93**	.77**	.43**	.71	.27	.90	.06	.94**	.93**
Separable foreshank lean	.85**	.82**	.61**	.30*	.55	.50	.75	.22	.94**	.85**
Separable sirloin lean	.84**	.74**	.61**	.34**	.53	.51	.66	.21	.93**	.77**
Separable shortloin lean	.77**	.70**	.66**	.32*	.39	.57	.62	.25	.88**	.74**
Separable rib lean	.79**	.71**	.67**	.34**	.42	.55	.63	.24	.89**	.75**
Separable 9-10-11 rib lean	.78**	.76**	.70**	.35**	.39	.56	.69	.21	.88**	.79**
Carcass weight	.83**	.45**	...	...	...	...	...	...	...	...

[a] Includes data on 63 steers of known heredity.
[c] Standard partial regression coefficient of separable carcass lean on X_1 when carcass weight is held constant.
[d] Standard partial regression coefficient of separable carcass lean on carcass weight when X_1 is held constant.
* Denotes significance P=.05.
** Denotes significance P=.01.

separable lean of the carcass was considered a linear function of carcass weight and separable lean of either the round or foreshank. The multilinear correlation coefficients were 0.97, 0.94, and 0.89, respectively.

Since over the whole body of data, loin eye area was not closely related to separable lean and since differences with respect to type and breed were known in part of the data, it seemed advisable to investigate what influence,

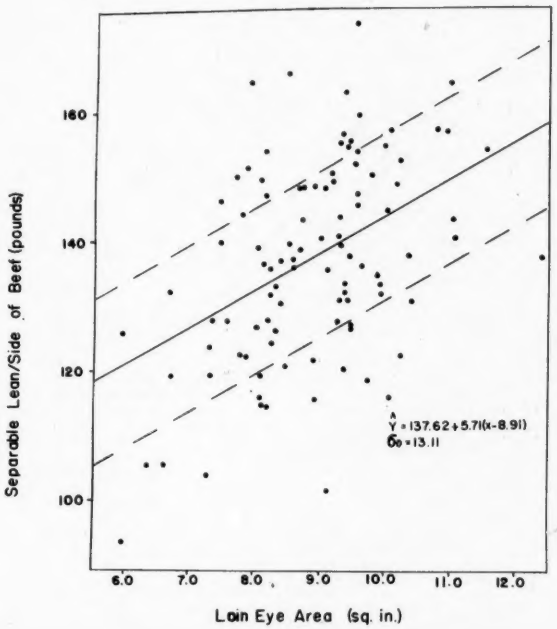

Figure 1. Regression of separable carcass lean on loin eye area.

if any, differences among breeds would have on these same relationships. Table 3 shows the simple and multiple correlation and the standard partial regression coefficients of separable lean in the whole and in various cuts on carcass weight, computed within year ignoring breed as contrasted to those calculated on a within year and breed basis for the 63 steers from the types and breeds study. The simple correlations between loin eye area and the other variables within year tended to be higher than those in table 1. When breed effects were eliminated, loin eye was a poorer predictor of carcass leanness than when breed effects were ignored. On the other hand,

when the effects of breed were considered, separable lean of the round, chuck, foreshank, or 9–10–11 rib section were equally as good predictors of carcass leanness, as when breed was ignored (table 4). With the effects of carcass weight and breed eliminated, 56 to 82% of the variation in carcass leanness was accounted for by either the separable lean of the round, chuck, or foreshank (table 4). Since the relationship of carcass

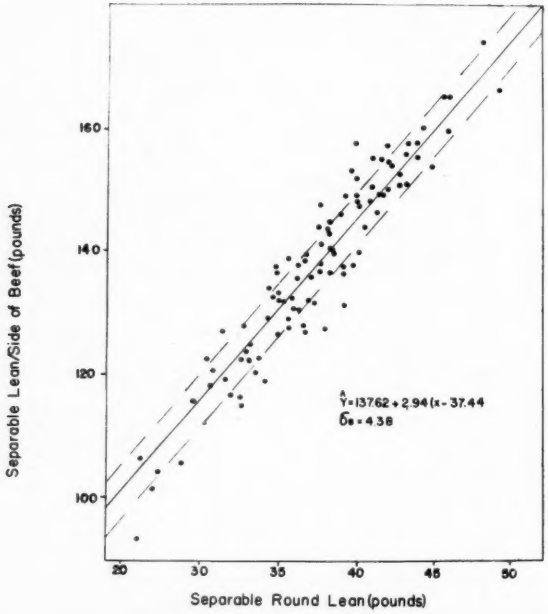

Figure 2. Regression of separable carcass lean on separable lean of the round.

weight with separable carcass lean was greatly reduced when computations were made on a within year and breed basis as compared when breed was ignored and within year, it was evident that some weight effect was due to breed differences.

Several regression lines were plotted from data on the 99 cattle. The standard deviation of total separable lean within year was 14.29 lb. of lean. Figure 1 shows the regression of separable carcass lean on the area of loin eye. The regression equation was $Y=137.62+5.71\ (X-8.91)$, with a standard error of the estimate of 13.11 lb. of carcass lean. Regression of total separable lean upon loin eye area accounted for only 18%

of the variation in total lean. The standard deviation and standard error of estimate from the above equation shows only a slight reduction of variability in terms of absolute values when the linear effect of loin eye area was removed.

The regression equation of separable carcass lean on separable round lean was found to be $Y=137.62+2.94\ (X-37.44)$, with a standard error

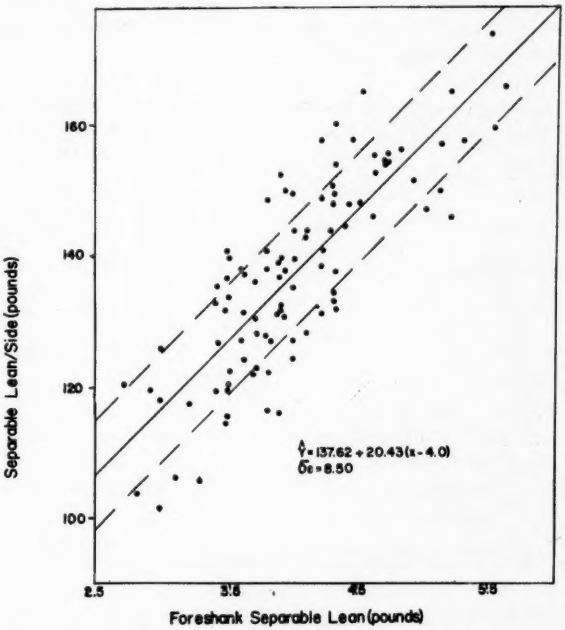

Figure 3. Regression of separable carcass lean on separable lean of the foreshank.

of 4.38 lb. of separable carcass lean. With each 1.0 lb. increase in round separable lean, there was a corresponding increase of 2.94 lb. in the separable lean of a side of beef. Contrary to the regression of carcass lean on loin eye area (figure 1) the data fit the regression line closely in figure 2. It appears that separable lean of the round is a much better estimator of total carcass lean than loin eye area. Of all variables investigated, separable round lean gave the most precise estimate of total carcass muscling.

Figure 3 shows the relationship between carcass lean and lean of the

foreshank, which also may have some value in predicting carcass leanness. The regression equation was Y=137.62+20.43 (X—4.0) and having a standard error of the estimate of 8.50 lb. Thus, each 1.0 lb. increase in the lean content of the foreshank was associated with a corresponding increase of 20.43 lb. of separable carcass lean.

Regression equations of 137.62+2.85 (X—41.37), 137.62+7.36 (X—11.81), and 137.62+17.62 (X—4.36) with standard errors of 5.51, 8.88, and 9.84 lb. of carcass lean were found with separable carcass lean upon the separable lean of the chuck, rib, and 9–10–11 rib section, respectively.

Linear Carcass Measurements. Table 5 presents the correlation coeffi-

TABLE 5. SIMPLE CORRELATION COEFFICIENTS OF VARIOUS LINEAR CARCASS MEASUREMENTS AND WEIGHT OF BONE IN THE CARCASS WITH LOIN EYE AREA AND SEPARABLE CARCASS LEAN

X	Loin eye area with	Separable carcass lean with
Carcass length	—.13	0.39
Leg length	0.02	.53
Loin length	—.06	.44
Round circumference	0.32	.45
Round width	0.27	.06
Chuck width	0.50	.18
Depth of flank	0.16	.59
Depth of chest at 5th rib	—.21	.26
Loin eye area X carcass length	....	.55
Bone carcass (weight)	0.14	.75

0.250 required for significance at P=.05.
0.325 required for significance at P=.01.

cients of the various linear carcass measurements and weight of the bone in the carcass with loin eye area and carcass separable lean. The relationships between the various linear carcass measurements and loin eye area were quite low, accounting for 25% or less of the variation existing in the area of loin eye. Circumference of round and width of either the round or chuck showed the highest relationships. The total weight of the bone from the carcass likewise had little relationship to loin eye area. On the other hand, the measurements more descriptive of carcass length (carcass length, length of round, and length of loin), circumference of round, and depth of flank appeared to be more indicative of total separable carcass lean (accounting for 15–35% of the variation) than were the various measurements depicting thickness. The weight of the cannon bones have been reported to show a strong relationship to carcass leanness (McMeekan 1956). In this study the correlation coefficient between the weight of separable carcass lean and separable carcass bone was 0.75.

The product of loin eye area and carcass length was more highly related to total separable lean than was either item taken alone (r=0.55).

Summary

The area of loin eye, carcass weight, the separable lean of a particular beef cut, and various linear carcass measurements were evaluated as to their usefulness for predicting total carcass leanness. The area of loin eye was associated with only 18% of the variation of separable carcass lean, and 5–30% of the variation in the separable lean of the more valuable cuts of beef. Likewise, the relationships of the various linear carcass measurements with either loin eye area or carcass separable lean were quite low. Carcass width and circumference measurements were more highly related to loin eye area, while the various linear measurements descriptive of carcass length were closely related to total lean. Bone weight of the entire carcass was highly related to total separable carcass lean (r=0.75).

The separable lean of a particular cut of beef was found to be more descriptive of carcass leanness or muscling than either the area of loin eye or the various carcass measurements. Correlation coefficients between total separable carcass lean and the lean of various wholesale cuts were 0.95 with round, 0.93 with chuck, 0.81 with foreshank, 0.80 with sirloin, and 0.75 with shortloin. From the regression equations calculated from these data, total carcass lean was found to increase by 2.94 and 20.43 lb. for each pound increase in separable round or foreshank lean, respectively. The high relationship of the lean content in these and other beef cuts (especially the round), to the total lean of the carcass is indicative of their usefulness to predict total carcass muscling in a particular beef carcass.

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EFFECT OF EXOGENOUS PROGESTERONE ON THE CORPORA LUTEA OF HYSTERECTOMIZED GILTS [1]

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THE corpus luteum is maintained for prolonged intervals in the hysterectomized cow and ewe (Wiltbank and Casida, 1956), guinea pig (Loeb, 1927), rabbit (Asdell and Hammond, 1933; Loeb and Smith, 1936; Gillard,1937; Chu *et al.*, 1946) and rat (Bradbury, 1937; Hechter *et al.*, 1940). No effect of hysterectomy on the corpus luteum has been observed in certain other species, e.g., opossum (Hartman, 1925) and monkey (Burford and Biddle, 1936).

The reason the corpus luteum is maintained in the absence of the uterus is not known. Robson (1937), Chu *et al.* (1946) and Lyons *et al.* (1943) reported that the corpora lutea of the rat and rabbit can be maintained by injections of estrone. Pincus (1937) indicated that injections of estrone in the intact rabbit increased the estriol in the urine, but injections in the hysterectomized animal did not produce this effect. The simultaneous injection of estrone and progesterone into non-pregnant animals resulted in an increased excretion of estriol; furthermore, pregnant and pseudopregnant animals excrete two to five times the amount of injected estrogen as non-pregnant animals. Hechter *et al.* (1940) and Chu *et al.* (1946) demonstrated that transplantation of uterine tissue into hysterectomized rats or rabbits resulted in regression of the corpora lutea which suggests that estrogen may be converted to inactive forms in the presence of a functional uterus and that progesterone may speed the rate of this conversion.

Sammelwitz *et al.* (1956) and Spies *et al.* (1957, 1959) reported that exogenous progesterone treatment resulted in regression of the corpora lutea in pregnant gilts.

The purpose of the present study was to determine if removal of the uterus in the gilt would prolong the life of the corpora lutea and to determine the effect of injected progesterone and uterine transplants on the corpora lutea of hysterectomized gilts.

Materials and Methods

In trial A, four market gilts (3 cycling and 1 bred) were hysterectomized [2] seven days after beginning of estrus. A 12% chloralhydrate-6%

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magnesium sulfate solution was used as an anesthetic at the rate of 1 cc. per lb. body weight given intraperitoneally. The uterine blood supply and the cervix near its caudal end were ligated and the uterus removed (from mid-cervix to tubo-uterine junction) avoiding damage to the ovarian blood supply. A small amount of India ink was injected beneath the tunica albuginea of some of the corpora lutea from each gilt. The gilts were checked daily for estrus following hysterectomy until slaughter at 32, 71, 72 and 119 days post estrus.

In trial B, 32 market gilts ranging in weight from 165 to 270 lb. were assigned at random to four experimental groups. The gilts were checked once daily for estrus by a vasectomized boar and were bred artificially on the first day of estrus (day-0) with 100 cc. of fresh semen from one of seven boars known to be fertile. The four groups were pregnant gilts, pregnant gilts injected with progesterone, gilts hysterectomized on the seventh day of pregnancy, and gilts hysterectomized on the seventh day of pregnancy and then injected with progesterone. Progesterone was injected daily subcutaneously in corn oil (25 mg./cc.) from day-10 to slaughter. All gilts were slaughtered on day-25 of gestation. The gilts were allowed to eat a balanced ration *ad libitum*. Hysterectomized gilts were taken off feed 24 hr. prior to the operation. The anesthetic and surgical procedure were the same as indicated in trial A. Uteri from the hysterectomized gilts were flushed and the blastulae were recovered and studied under a low power binocular microscope to establish their identity. All of the hysterectomized gilts were pregnant on day-7; data on unoperated gilts at 25 days were included in the analysis only if they were pregnant at that time thus accounting for the different numbers in the various groups. Immediately following slaughter the corpora lutea were excised, counted, weighed and stored in 95% ethanol at approximately —5° C. for chemical analysis of progesterone content by the method of Loy, *et al.* (1957). Corpora lutea weights were analyzed statistically by a multiple range test (Duncan, 1955), while progesterone concentrations of the corpora lutea because of their abnormal distribution were analyzed by the H test (Kruskal and Wallis, 1952).

A series of exploratory experiments also was carried out. Two gilts were laparotomized on day-18 of pregnancy. Four mg. of progesterone in a supersaturated solution of propylene glycol were injected directly into two of the corpora lutea on one ovary in each of these two gilts. These same corpora lutea were marked with India ink. Two corpora lutea on the other ovary of one of these gilts were injected with India ink and propylene glycol. Corpora lutea were not present on the other ovary of the second gilt. Both gilts were slaughtered at day-25 of pregnancy and the corpora lutea weighed. Four other gilts received transplants of uterine tissue. Autotransplants of 1¼ uterine horns in one gilt and of the entire uterus in two gilts were made on the seventh day of the estrual cycle. A homotransplant of the entire uterus from a gilt in the follicular phase

(19th day of the cycle) was made into the fourth gilt at the time of hysterectomy on the 11th day of the cycle. The uterus in the first gilt was placed partly in the subcutaneous tissue of the belly region and partly between the lumbar muscle layers. It was sutured back to the broad ligament in the other three gilts. Still another gilt in this series had a 2-in. segment of each broad ligament associated with the middle uterine arteries sectioned. Surgical procedure for the gilts receiving the uterine transplants and the gilt with the sectioned broad ligaments was the same as previously described. The corpora lutea were marked as indicated in trial A and the gilts were checked daily for estrus. The gilts receiving autotransplants of the uterus were slaughtered 30 days from their previous estrus, whereas the gilt receiving the estrual phase uterine transplant was slaughtered 24 days from her previous estrus. The corpora lutea were weighed and samples of the uterine transplants taken for histological study. The gilt with the sectioned broad ligaments was slaughtered on the day of heat.

Results

Removal of the uterus on the seventh day of the estrual cycle or on the seventh day of pregnancy in trial A resulted in maintenance of the corpora lutea in all cases. The average individual corpus luteum weights for each of the four gilts slaughtered at 32, 71, 72 and 119 days post estrus were 484, 486, 305 and 414 mg., respectively, while the progesterone concentrations expressed as micrograms of progesterone per gram of luteal tissue were 57, 79 and 12 for three of the gilts (table 1). No chemical determination was made on the gilt autopsied at 72 days post heat because of post mortem changes, which probably account for the lowered corpora lutea weight also. The data suggest the corpora lutea were maintained in hysterectomized gilts for an interval which at least approximates the gestation period.

In trial B the average individual corpora lutea weights were 419, 178, 421 and 181 mg. for the pregnant, pregnant-injected-with-progesterone, hysterectomized and hysterectomized-injected-progesterone groups, respectively (table 1). Progesterone treatment reduced the corpora lutea weight significantly. No significant difference in corpora lutea weights existed between the hysterectomized group and the normal pregnant group, nor were the corpora lutea weights significantly different between the two groups which received progesterone (hysterectomized and pregnant; table 2).

Progesterone concentrations (expressed as micrograms of progesterone per gram of luteal tissue) for the pregnant, pregnant-injected-with-progesterone, hysterectomized and hysterectomized-injected-with-progesterone groups averaged 34, 19, 42 and 26 mcg./gm., respectively. These means were not significantly different, although the values for the two groups which received progesterone treatment were somewhat lower than the values for the non-progesterone treated groups (table 1).

TABLE 1. AVERAGE INDIVIDUAL CORPUS LUTEUM WEIGHT, PROGESTERONE CONCENTRATION AND WITHIN CLASS REGRESSIONS OF PROGESTERONE CONCENTRATION ON AVERAGE INDIVIDUAL CORPUS LUTEUM WEIGHT

Item	No. days from preoperative heat to slaughter	No. of animals	(A) Average individual corpus luteum weight (mg.)	(B) Progesterone concentration (mcg./g.)	b_{BA}[d]
Gilt no.					
109[a]	32	1	484	57	
108[a]	71	1	486	79	
202[b]	72[c]	1	305	..	
241[a]	119	1	414	12	
Group					
Pregnant	25	4	419	34	—0.12
Pregnant+ progesterone	25	6	178	19	0.18
Hysterectomy	25	8	421	42	—0.11
Hysterectomy+ progesterone	25	8	181	26	0.17

[a] Cycling gilt.
[b] Bred 7 days prior to hysterectomy.
[c] Died because of a rupture resulting from the operation and the corpora lutea did not exsect cleanly from the ovaries as they were not processed until approximately 5 hours after death.
[d] Within group regressions were heterogeneous ($P<.05$).

The regressions of progesterone concentration on average individual corpus luteum weight for the four groups were heterogeneous indicating progesterone treatment had affected the linear association of these two variables (table 1).

In the series of exploratory experiments local injections of progesterone directly into the corpora lutea had no measurable influence on average individual corpus luteum weight. Two progesterone treated corpora lutea from each of two gilts averaged 413 and 412 mg. as compared to an average of 471 and 407 mg. for six and 10 untreated corpora lutea from the same gilts. Two injected control corpora lutea (glycol plus ink) from one of the gilts averaged 429 mg. In the four gilts which received transplants of luteal or estrual phase uterine tissue the ovaries contained corpora

TABLE 2. MULTIPLE RANGE TEST FOR AVERAGE INDIVIDUAL CORPORA LUTEA WEIGHT (1% LEVEL)

Group	Pregnant	Pregnant+ Progesterone	Hysterectomy	Hysterectomy+ Progesterone
Mean	181	178	419	421
n	4	6	8	8

lutea marked with India ink indicating that they were the same corpora lutea which were present at the time of hysterectomy and transplantation. The average individual corpus luteum weights for each of the four gilts were 520, 475, 593 and 517 mg. Two of the four gilts had 10–13 follicles ranging from 3 to 7 mm. in diameter on their ovaries, but there was no real evidence that the uterine transplants had replaced the role of the intact uterus. Sectioning an area of the broad ligament associated with the middle uterine arteries had no effect on the corpora lutea as indicated by regression of the corpora lutea and the recurrence of estrus 21 days following the previous heat.

Discussion

The corpora lutea of hysterectomized gilts were maintained for a prolonged interval and in one case that was allowed to continue, the interval exceeded the average gestation period. Loeb (1927) reported hysterectomy in the guinea pig prolonged the corpora lutea beyond the normal 60-day gestation period. The values of progesterone concentration and average individual corpus luteum weight for the gilts in trial A were comparable to values for normal 25-day pregnant gilts as indicated in trial B and 70-day pregnant gilts (Loy *et al.*, 1958). The low value of progesterone concentration for the gilt slaughtered at 119 days post heat may suggest a decreasing function of the corpora lutea at that stage. No large follicles were present on the ovaries of any of the hysterectomized gilts slaughtered at the various stages. Wiltbank and Casida (1956) noted large follicles in hysterectomized heifers and ewes. Whether this indicates a difference in the effect of hysterectomy on the level of ovarian function between these species is not known. It may have been due to a more complete removal of the uterus in the gilts, since none of the cervix was removed in the ewes or heifers.

The regression of the corpora lutea in the hysterectomized gilts treated with progesterone in trial B indicated that the exogenous progesterone is not having its effect via the uterus. Also, it probably is not acting directly since local injections of progesterone directly into the corpora lutea did not influence the average individual corpus luteum weight. It is presumed that the progesterone injected systemically was blocking the release and/or production of a corpus luteum maintaining substance from some source such as the anterior pituitary gland. Evidence indicates this substance is probably not prolactin as 25 or 50 mg. of prolactin daily failed to prevent the regression of corpora lutea in the progesterone-treated-pregnant gilt (Sammelwitz and Nalbandov, 1958).

Examination of the histological sections of the uterine transplants suggested that the endometrium was at least partially functional; if so, this refutes the hypothesis for a uterine hormone or a metabolic function of the uterus. In experiments of this type one can be certain of an adequate "take" only if positive results are obtained; therefore, additional informa-

tion is needed before these two possibilities can be excluded. Loeb (1927) reported uterine transplants could not replace the intact uterus in the hysterectomized guinea pig.

Evidence of a possible neural stimulus from that area of the endometrium which is supplied by nerves associated with the middle uterine arteries affecting corpus luteum maintenance was not obtained in this study. Whether a relationship between other uterine nerves and corpus luteum maintenance exist in swine is not known. Nalbandov *et al.* (1955) demonstrated that beads implanted into the uterus of ewes on the 8th day of the estrual cycle prolonged the cycle length, whereas the cycle was shortened when beads were implanted on the third day. Implanting on the 13th day had no effect. Denervation of the uterine section which received the beads removed their effect. They suggested the capacity of the uterine nerves to respond to the stimulus of the beads or the capacity of the hypothalamic center or pituitary gland to respond to stimuli from the uterus was altered by circulating levels of estrogen and progesterone. Selye (1934) reported paraffin placed in the uterus of the rat after removal of the fetuses resulted in the corpora lutea being maintained, while in non-paraffin treated rats the corpora lutea regressed soon after removal of the fetuses.

Summary

Four gilts (three open and one bred) were hysterectomized 7 days after the beginning of heat. The corpora lutea were marked with India ink. None of the gilts exhibited estrus before slaughter at 32, 71, 72 and 119 days post heat. The average individual corpus luteum weights and progesterone concentrations of the corpora lutea for the four gilts were 484 mg., 57 ug.; 486 mg., 79 ug.; 305 mg. (not determined); and 414 mg., 12 ug., respectively. Thus hysterectomy caused retention of the corpora lutea for prolonged intervals.

Another experiment involving 32 market gilts was designed to study the effect of progesterone injections on maintenance of the corpora lutea in hysterectomized gilts. All animals were bred on the first day of estrus (day-0); hysterectomy was performed on day-7 and slaughter was on day-25. Progesterone was injected subcutaneously daily from day-10 to slaughter at the rate of 1 mg. per lb. body weight per day. Four groups of gilts were involved: pregnant, pregnant-injected-with-progesterone, hysterectomized, and hysterectomized-injected-with-progesterone. The average individual corpus luteum weights and progesterone concentrations of the corpora lutea from the four respective groups were 419 mg., 34 mcg.; 178 mg., 19 mcg.; 421 mg., 42 mcg.; and 181 mg., 26 mcg. Progesterone treatment reduced the corpora lutea weight in both the hysterectomized and non-hysterectomized groups. There was no significant effect of hysterectomy or progesterone treatment on the mean progesterone concentration of the

corpora lutea, but progesterone brought about a positive regression of concentration on corpus luteum weight.

Local injections of 4 mg. of progesterone directly into the corpora lutea on the 18th day of pregnancy produced no measurable influence on the average individual corpus luteum weights in two gilts at the 25th day of pregnancy. Two progesterone-treated corpora lutea from each of the two gilts averaged 413 and 412 mg. as compared to an average of 471 and 407 mg. for six and ten untreated corpora lutea from the same gilts.

Transplants of luteal or estrual phase uterine tissue into four gilts hysterectomized on day-7 or -11 of the cycle failed to cause regression of the corpora lutea. The average individual corpus luteum weights for the four gilts were 520, 475, 593 and 517 mg. at 24 to 30 days from their previous estrus. Another gilt in which the nerves associated with the middle uterine artery had been sectioned on day-7 of the cycle returned to heat 21 days post estrus. Evidence from these five gilts fails to demonstrate the role of the uterus in corpus luteum maintenance and regression.

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THE VALUE OF THE 12th RIB CUT FOR MEASURING BEEF CARCASS YIELDS AND MEAT QUALITY

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ONE of the most important problems confronting livestock research workers is the development of simple methods of measuring carcass yield and meat quality of beef cattle. Suitable carcass evaluation methods would aid materially in correcting the acute deficiency of lean and the surplus of waste fat found in the carcasses of a high percentage of our present-day beef cattle.

Hankins *et al.* (1939) studied the relationship of fat to quality and investigated other quality factors of meat animal carcasses. Data on 142 grain-fed steers showed that fatness was a major factor affecting the proportion of carcass in meat animals. Data from 84 steer carcasses yielded a correlation of $-.92 \pm .01$ between the fat (ether extract) content of the edible portion of the 9-10-11th rib cut and the water-content of the edible portion of the dressed carcass. Meat samples of the longissimus dorsi muscle from the 9-10-11th rib roasts of 728 cattle were used to secure correlations between indexes of fat and tenderness. The small magnitude of the correlations indicated that most of the variation in tenderness was due to factors other than fatness.

Cover *et al.* (1958), in tenderness studies, found that fatness was not as closely related to tenderness as formerly believed. Other factors may have greater importance in determining tenderness of beef. Research on more reliable methods of determining the real cause of tenderness in meat is needed.

In a study using the 6-7-8th, 9-10-11th and 12-13th rib cuts as three separate roasts, Alexander *et al.* (1939) reported that, on the average, the evaporation loss decreased as the grade of beef increased. Drip losses, however, increased as the grade of beef increased. In this test, oven temperature was the most important single factor influencing shrinkage and cooking time.

Hankins *et al.* (1943, 1946) found that certain constituents of the 9–10–11th rib cut of the steer carcass were very closely related to the corresponding constituents of the dressed beef carcass. Correlation coefficients between the percent of separable lean, fat and bone of the 9-10-11th rib to the percent of separable dressed carcass lean, fat and bone were 0.90, 0.93 and 0.80, respectively.

In a beef carcass study conducted by Callow (1948), the ratio of lean

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to bone remained rather constant until 20% fatty tissue had been reached. Past that point, the ratio decreased as fatty tissue increased.

Crown (1953) reported highly significant correlations between carcass quality data from the 12th rib cuts and the 9-10-11th rib cuts collected on the carcasses of fifty-three steers. Cole *et al.* (1959) reported highly significant correlations between the separable lean of various beef cuts and the separable dressed carcass lean. They did not report on the 12th rib cut.

The current study was started in 1955 at the Louisiana Agricultural Experiment Station to investigate further cooking data collected on the 12th rib cut in comparison to that collected on the 9-10-11th rib cuts. One major objective of the study, as reported in the current paper, was to determine how closely the constituents of the 12th rib cut are related to the corresponding constituents of the 9-10-11th rib cut and the dressed carcass. The criteria of evaluation in the study were cooking losses and percentage of separable lean, fat and bone.

Experimental

Seventy-three purebred and crossbred beef cattle from the Louisiana State University experimental herds contributed data to this study. The animals were slaughtered at the L.S.U. abattoir, and slaughter and carcass quality data were collected in the L.S.U. meats laboratory. All carcasses were cut and rib roasts were removed according to the specifications recommended by the Reciprocal Meats Conference (Wellington, 1953).

Cooking Loss Studies. The samples used in this phase of the study were the 12th rib cut and the 9-10-11th rib cut from the left side of 49 carcasses. The carcasses averaged 443 lb. in weight, and Federal carcass grades were distributed as follows: 3 Prime, 22 Choice, 17 Good, and 7 Standard. The carcasses were chilled for 72 hours at 33° F. The left sides were ribbed down, tracings were made at the cross-section of the rear edge of the 12th rib, and the carcasses were graded by a committee according to U. S. Federal grades. The cuts were labeled, securely wrapped in laminated locker paper, relabeled, and stored at 36° F. until they were cooked on the seventh day after slaughter. The two roasts to be compared from each carcass were roasted in the same oven at 300° F. in separate pans until the roasts reached a center internal temperature of 58° C. The roasts were taken from the oven and weighed to determine the evaporation loss, drip loss, and total cooking losses.

Physical Composition Studies. Twenty-four beef animals were used in this phase of the study. Their sex and breeding were: 2 Africander steers, 6 Africander x Angus steers, 3 Africander x Brangus steers, 3 Africander x Shorthorn-Hereford steers, 2 Africander x Angus-Hereford steers, 2 Africander x Charbray-Hereford steers, 2 Hereford steers, 1 Africander x Shorthorn-Angus steer, 1 Africander x Hereford-Angus steer, 1 Africander

x Hereford steer, and 1 Shorthorn heifer. The carcasses averaged 424 lb. in weight. The array of Federal carcass grades was as follows: 1 Prime, 1 Choice, 17 Good, 4 Standard, and 1 Utility. The left sides of the 24 beef carcasses were ribbed down, and the 12th rib cut and the 9-10-11th rib cuts were removed. The left side of each beef carcass, including the two rib roasts, were physically separated into separable lean, fat and bone. Weights were taken on each component.

The data were evaluated statistically according to the correlation coefficient method described by Snedecor (1946).

Results and Discussion

Cooking Loss. The correlation coefficients between cooking losses of the 12th rib roasts and the 9-10-11th rib roasts from 49 steers of Prime through

TABLE 1. CORRELATION COEFFICIENTS OF PERCENTAGE COOKING LOSSES OF 12TH RIB CUT AND 9-10-11TH RIB CUT

Correlation between—	Correlation coefficient	Standard error of estimate
% Evaporation loss of 12th rib cut and % evaporation loss of 9-10-11th rib cut	0.62**	0.115
% Drip loss of 12th rib cut and % drip loss of 9-10-11th rib cut	0.69**	0.105
% Total loss of 12th rib cut and % total loss of 9-10-11th rib cut	0.65**	0.111

** Significant at the 1% level.

Standard grade are given in table 1. The correlation coefficients for percent evaporation, drip and total cooking losses of the 12th rib, with the 9-10-11th rib cuts were 0.62, 0.69 and 0.65, respectively. All three correlations were significant at the 0.01 level of probability.

Physical Separation on Roasts and Dressed Carcasses. Table 2 shows percentages of separable lean, fat and bone in the 12th rib cuts and the 9-10-11th rib cuts with the percentages of dressed carcass separable lean, fat and bone from twenty-four beef carcasses.

The correlation coefficients for percentages of separable lean, fat, and bone of the 9-10-11th rib cut with the dressed carcass separable lean, fat and bone were 0.943, 0.976, and 0.733, respectively. All of these correlations were highly significant. The correlation coefficients for percentages of separable lean, fat, and bone of the 12th rib cut with the dressed carcass separable lean, fat, and bone were 0.818, 0.962 and 0.750, respectively. Thus, the two sets of correlations of the separable constituents of the 12th rib cut and 9-10-11th rib cut with the separable constituents of the total carcass indicate that these cuts have comparable predictive values. Data

collected from either cut will provide good estimates of total carcass composition.

The correlation coefficients for percentages of separable lean, fat and bone of the 12th rib cut with the percentages of separable lean, fat and bone of the 9-10-11th rib cuts were 0.825, 0.965 and 0.850. These highly significant correlations reveal the close relationship of the two cuts.

When the 12th rib cut is removed for carcass quality studies, the carcass is not greatly impaired or devaluated. Thus, when experimental animals must be handled at packing plants or slaughter plants, the 12th rib from each side of the carcass may be collected after carcasses are graded. These roasts may be transported to the institutional laboratory to complete the

TABLE 2. CORRELATION COEFFICIENTS BETWEEN SEPARABLE LEAN, FAT, AND BONE OF 12TH RIB CUT AND 9-10-11TH RIB CUT AND WITH TOTAL CARCASS SEPARABLE LEAN, FAT AND BONE ON 24 BEEF CARCASSES

	9-10-11th Rib cut			Total Carcass		
Item	Separable lean	Separable fat	Bone	Separable lean	Separable fat	Bone
12th Rib cut						
Separable lean	0.825**	.....	.....	0.818**	.....	.....
Separable fat	.....	0.965**	.....	.....	0.962**	.....
Bone	.....	.....	0.850**	.....	.....	0.750**
9-10-11th Rib cut						
Separable lean	.....	.....	.....	0.943**	.....	.....
Separable fat	.....	.....	.....	.....	0.976**	.....
Bone	.....	.....	.....	.....	.....	0.733**

** Significant at the 1% level.

collection of meat yields and meat quality data. Where limited meats research facilities are available this method of beef carcass evaluation could increase materially the amount of carcass quality data collected. Such information would help identify the more meaty, quality strains of cattle and would facilitate the improvement of carcass yields and meat quality of present types and breeds of beef cattle.

Summary

A study was initiated in 1955 to evaluate the cooking data and physical composition data collected on the 12th rib cut from both sides of beef carcasses in depicting carcass yield and meat quality. An analysis of the results, with respect to cooking loss and separable fat, lean and bone and other carcass quality measurements, indicates that the 12th rib cut can be used to predict the carcass yield and meat quality of beef cattle.

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MAINTENANCE OF EARLY PREGNANCY IN OVARIECTOMIZED GILTS TREATED WITH GONADAL HORMONES[1]

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PRENATAL mortality in swine has been estimated at approximately 45% (Squires *et al.*, 1952; Casida, 1953). Perry (1954) reported that a large proportion of prenatal loss occurs during the first 25 days of gestation. du Mesnil du Buisson and Dauzier (1957) demonstrated that the ovaries are essential for the maintenance of pregnancy throughout most of the gestation period in swine.

A quantitative relationship was reported by Jost (1939) between the amount of progesterone injected and the number of embryos surviving until near term in ovariectomized rabbits. Glasgow *et al.* (1951) reported a significant correlation between progesterone excretion products and percentage of embryo survival in swine. Thus it is theoretically possible that non-optimum levels of progresterone and/or estrogen may be responsible for a part of the prenatal mortality that occurs. Sammelwitz *et al.* (1956) and Spies *et al.* (1957, 1959) reported lowered survival rates in progesterone-treated gilts as compared to controls during the first 25 days of pregnancy. The endogenous hormonal levels in these animals were not known; an estimate of the hormonal requirements for maintenance of pregnancy in the ovariectomized gilt should be useful information.

Materials and Methods

Thirty-six market gilts of mixed breeding ranging in weight from 190 to 260 lb. were assigned at random in equal numbers to one of four experimental groups. One of the experimental groups was designated as controls and the other three were ovariectomized and injected with hormones.

The gilts were checked for heat daily with a vasectomized boar and mated to one of two fertile boars on the first day of heat. An initial hormone injection was given to the hormone-treated animals 72 hours after mating and bilateral ovariectomy by laparotomy was performed 96 hours after mating. A 12% choralhydrate-6% magnesium sulphate solution was used as an anesthetic at the rate of 1cc. per lb. body weight given intraperitoneally.

The three treated groups received daily per pound of body weight: group 1, 0.03 mg. of progesterone plus 0.075 mcg. of estrone, group 2, 0.6

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mg. of progesterone plus 0.15 mcg. of estrone, and group 3, 1.2 mg. of progesterone plus 0.3 mcg. estrone. The hormones thus were given to all treated animals at a ratio of 4000 parts of progesterone to one part of estrone. Injections were given subcutaneously in corn oil at a progesterone concentration of 25 mg. per cc. and were continued until the animals were slaughtered on the 25th day of gestation. Corpora lutea counts were taken at the 4th day in the ovariectomized groups and at the 25th day in the control group. The numbers of live and dead embryos present and the embryo and membrane weights were recorded. The numbers of corpora lutea were used as bases for estimating embryo survivals. The percentage of embryo survival was adjusted for the estimated amount of uterine horn adhesion in the ovariectomized groups using a within group regression of embryo surivival on amount of adhesion. The amount of adhesion was classified as 1 (light) in six gilts, 2 (moderate) in ten gilts or 3 (severe) in four gilts. There was an estimated 19.2% decrease in embryo survival for each unit increase in amount of uterine horn adhesion. The adjusted percentages of embryo survival were transformed to angles for the analysis.

Results and Discussion

The percentages of embryo surivival based on all gilts and the average number of live embryos per pregnant gilt for the three ovariectomized-hormone-treated groups were significantly lower than for the control group, and the survival rates or number of live embryos of the three treated groups did not differ significantly (tables 2 and 4). This may indicate that the dosage levels were either too high or too low or that the ratio of progesterone and estrone given was not optimal for maximum

TABLE 1. EMBRYO SURVIVAL, NUMBER OF LIVE AND DEAD EMBRYOS AND EMBRYO AND MEMBRANE WEIGHTS AT DAY-25 OF GESTATION

Treatment [a]	No. pregnant / No. in group	Embryo survival [b]	Av. no. live embryos present at autopsy [c]	Av. no. dead embryos present at autopsy [c]	Embryo weight (gm.) [d]	Membrane weight (gm.) [d]
Normal-pregnant (controls)	8/9	86	11.8	0	0.51	9.2
0.3 mg. Progesterone: 0.075 mcg. Estrone	8/9[e]	17	4.1	3.6	0.39	5.9
0.6 mg. Progesterone: 0.15 mcg. Estrone	8/9	45	4.6	2.1	0.47	7.8
1.2 mg. Progesterone: 0.3 mcg. Estrone	9/9	38	5.2	1.8	0.48	7.7

[a] Hormone dosage was administered on a per pound body weight per day basis.
[b] Percent embryo survival based on all nine animals in the group. Percentages were transformed to angles and the average angle transformed back to percent.
[c] Average number of live and dead embryos based on pregnant gilts only.
[d] Means for embryo or membrane weights did not differ significantly.
[e] Two of the pregnant gilts had no live embryos at autopsy.

TABLE 2. MULTIPLE RANGE TEST FOR EMBRYO SURVIVAL OF ALL GILTS PER GROUP (ADJUSTED FOR ADHESION SEVERITY) [a]

Item	0.3 mg. Progesterone: 0.075 mcg. Estrone	0.6 mg. Progesterone: 0.15 mcg. Estrone	1.2 mg. Progesterone: 0.3 mcg. Estrone	Normal pregnant
Mean	25	38	42	68
n	9	9	9	9

[a] 5% Level of probability.

TABLE 3. MULTIPLE RANGE TEST FOR TOTAL NUMBER (LIVE AND DEAD) EMBRYOS OF PREGNANT GILTS [a]

Item	0.6 mg. Progesterone: 0.15 mcg. Estrone	1.2 mg. Progesterone: 0.3 mcg. Estrone	0.3 mg. Progesterone: 0.075 mcg. Estrone	Normal pregnant
Mean	6.7	7.0	7.7	11.8
n	8	9	8	8

[a] 5% Level of probability.

survival rate. The proportion of gilts pregnant at day-25 in the three treated groups was as large as that in the control group (table 1). This suggests that a more critical level and/or ratio of the gonadal hormones is required for maximum embryo surivival than for maintenance of pregnancy. Foote *et al.* (1957) and Lyons (1943) reported a ratio of 4000 parts of progesterone to one part estrone was moderately satisfactory for maintenance of pregnancy in the ewe and rat respectively.

There was a significantly greater average number of dead embryos per pregnant gilt in the treated groups as compared to the control group (table 5). The group receiving the lowest hormone treatment had a

TABLE 4. MULTIPLE RANGE TEST FOR NUMBER OF LIVE EMBRYOS OF PREGNANT GILTS [a]

Item	0.3 mg. Progesterone: 0.075 mcg. Estrone	0.6 mg. Progesterone: 0.15 mcg. Estrone	1.2 mg. Progesterone: 0.3 mcg. Estrone	Normal pregnant
Mean	4.1	4.6	5.2	11.8
n	8	8	9	8

[a] 5% Level of probability.

TABLE 5. MULTIPLE RANGE TEST FOR NUMBER OF DEAD EMBRYOS OF PREGNANT GILTS [a]

Item	Normal pregnant	1.2 mg. Progesterone: 0.3 mcg. Estrone	0.6 mg. Progesterone: 0.15 mcg. Estrone	0.3 mg. Progesterone: 0.075 mcg. Estrone
Mean	0	1.8	2.1	3.6
n	8	9	8	8

[a] 5% Level of probability.

significantly greater average number of dead embryos than the group receiving the highest hormone level at autopsy. The presence of dead embryos in the treated groups at day-25 gestation suggests that the dosage level and/or ratio was inadequate in the later part of the experimental period. However the significantly greater total number of embryos at autopsy in the control group as compared to the treated groups (table 3) indicates that the embryonic loss late in the experimental period did not account for the total difference in litter size at day-25 between control and treated groups. Day *et al.* (1959) reported a ratio of 2000 parts of progesterone to one part of estradiol benzoate at a dosage level of 1 mg. progesterone plus 0.5 mcg. estradiol per lb. body weight per day in gilts ovariectomized on the 15th day of pregnancy maintained survival to day-25 of gestation in 13 of 17 gilts. The percentage survival, based on the 13 pregnant gilts, was 11% higher than the percentage survival of intact controls. Roth *et al.* (1941) showed that estrogen was present in detectable amounts in the urine of pregnant sows between days 20–30 of gestation. Positive tests for estrogen were not obtained prior to the 20th day or after the 32nd day until late in gestation. These data suggest that the amount of estrogen present during the late experimental period may have been low in the hormone-treated groups.

There were no significant differences in embryo or membrane weights (table 1). Foote *et al.* (1957) reported heavier embryos in ovariectomized-hormone-treated ewes than in normal pregnant ewes during the first 25 days of pregnancy.

The group receiving 0.3 mg. progesterone plus 0.075 mcg. estrone per lb. body weight per day had a large number of dead embryos, a lower embryo surivival percentage, and smaller embryo and membrane weights than the other two treated groups. These consistently poorer results, although the latter three observations were statistically non-significant, suggested that this dosage level is not as desirable as the other hormone levels during the treatment period from day-4 to -25 of gestation.

Summary

Studies were made to determine the hormonal requirements for the maintenance of early pregnancy in swine. Nine control and 27 treated gilts were used. Ovariectomy was performed on day-4 and autopsy on day-25 of pregnancy. Subcutaneous injections of progesterone and estrone at a ratio of 4000:1 were administered in three different dosage levels per pound body weight, daily: (1) 0.3 mg. progesterone plus 0.075 mcg. estrone, (2) 0.6 mg. progesterone plus 0.15 mcg. estrone (3) 1.2 mg. progesterone plus 0.3 mcg. estrone. Injections were started 72 hours after breeding and were continued to slaughter.

The numbers of gilts out of nine that were pregnant at day-25 of gestation were 8, 8, 9 and 8 for the three treated and control groups, respec-

tively. The average percentages of embryo survival (for all gilts per group) and the average numbers of live embryos (per pregnant gilt) in the three treated groups were significantly less than for the control group (17, 4.1; 45, 4.6; and 38, 5.2 *vs.* 86, 11.8). There were significantly greater average numbers of dead embryos at autopsy in the three treated groups than in the control group (3.6, 2.1 and 1.8 *vs.* 0). The group receiving the lowest hormone level also had a significantly greater average number of dead embryos as compared to the group receiving the highest hormone level (3.6 *vs.* 1.8). Embryo and membrane weights averaged 0.39, 5.9; 0.47, 7.8; 0.48, 7.7; and 0.51, 9.2 gm. for the three treated and control groups respectively. These means were not significantly different.

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BETA RADIOACTIVITY OF THE ASH IN RELATION TO THE COMPOSITION OF HAM

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THE development of improved objective methods for estimating the composition of live animals, carcasses and meat cuts should increase the efficiency of the marketing operation. Techniques that would make it possible to estimate accurately the amount of lean, fat and bone in meat animals, carcasses and meat cuts would benefit the producer, the processor and the consumer.

Some recent studies suggest that natural potassium–40 radioactivity of animals may furnish an index of the muscle mass. In 1956 Woodward *et al.* reported that the total body potassium of a group of human subjects was related to the body water content and, therefore, to the lean body weight and muscle mass. The total body potassium content was determined by the use of a sensitive gamma-ray detector (the Los Alamos "human counter") which was capable of measuring the naturally present radioistope, potassium–40. Anderson (1957a) reported on the basis of potassium–40 and tritium dilution measurements with human subjects that the potassium content was 0.28% on a "fat-free" weight basis and was independent of the sex, age or weight of the subject. The possibility of estimating the muscle mass of a sample by a nondestructive technique suggests many applications and warrants further investigation. In preliminary study Kulwich, Feinstein and Anderson (1958) investigated the relationship of the fat content and the potassium–40 gamma radioactivity of four hams as measured in the Los Alamos "human counter". Measurements were made on the intact hams, then again after removing the skin and external fat, and finally on the lean portion with most of the fat trimmings removed. In each case the value for disintegrations per second of gamma rays per pound of sample was proportional to the percent of fat-free lean present.

The purpose of this study was to investigate further the relationship between the radioactivity emitted and the composition of meat samples.

Materials and Methods

Potassium–40 has an isotopic abundance of 0.0119%, a half life of about 1.25×10^9 years, and emits 10 beta particles for every gamma ray (Suttle

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[3] Appreciation is expressed to N. R. Ellis, R. L. Hiner and W. R. Kauffman of the Animal Husbandry Research Division, Agricultural Research Service, who made available the samples of ham lean and fat trimmings used in this study and supplied the ether extract protein, and moisture analyses.

and Libby, 1955). Potassium from different sources does not vary by more than ±.5% in its potassium–40 content (Vinogradov, 1957), so that a determination of the potassium–40 content of a biological sample should provide an excellent index of the total amount of potassium present. Potassium–40 is the principal naturally radioactive isotope present in all organisms. The data of Vinogradov (1957) indicate that, in the case of humans, there is about 7 times as much radioacitvity emitted by potassium–40 as there is by the next most prevalent naturally radioactive isotope, carbon–14. Because the preparation of samples for beta-radioactivity counting used in this study includes ashing which removes carbonaceous materials, potassium–40 is by far the predominant naturally radioactive material remaining in soft tissue ash.

Of the fission products resulting from atomic testing that may occur in meat, cesium–137 is probably of the greatest concern in connection with this study. Anderson *et al.* (1957b) reported that fresh hams analyzed had a cesium–137 to potassium–40 ratio of 0.30. The ashing procedure used in the present study may result in some volatilization of cesium. The ash samples were not analyzed for cesium content specifically. The total beta radioactivity of the ash was measured. In 1959 Laug and Wallace reported the results of a survey of radioactive residues in foods. There was no indication of significant amounts of beta radioactivity in the ash of meat-products samples above that which could be accounted for by the potassium content as determined by flame photometry. Since potassium and cesium are closely related chemically, belonging to the same group in the Periodic Table, cesium may follow potassium to some extent in its pattern of deposition. In this case, it might also tend to vary with the muscle mass. Anderson (1957a) reported that cesium followed to a rough approximation the potassium content in meat samples that were studied.

The samples used came from the right hams of 34 different hogs. The animals involved were 3 Duroc gilts, 9 Duroc barrows, 12 Yorkshire gilts and 10 Yorkshire barrows. Although these animals had varied treatment histories, there was no indication of any pronounced effect of prior treatment or sex difference upon the distribution of potassium in the tissue of the hams. These animals were slaughtered at around 180 lb. live weight. The right hams were dissected to separate the bone, fat trimmings and separable lean. The separable lean and the fat trimmings portions of each ham were handled separately. They were run through a meat grinder twice with thorough mixing before carrying out ether extract, protein and moisture analyses on samples according to A.O.A.C. methods (1955).

After chemical determinations were made, 36 samples were prepared for measurement of the beta radioactivity of the ash. These samples were dried and then ashed overnight at 550° C. in a muffle furnace. A 10-ml. portion of 1 *N* sulfuric acid was added to each sample before drying and ashing to minimize volatilization of potassium halide (Blaxter and Rook,

1956). Twelve of the samples consisted of 300 gm. of fat trimmings from 12 hams. The other 24 samples, two of which were from hams included among the 12 fat samples, consisted of various amounts of lean and fat trimmings from individual hams. The samples were dried and ashed in tared 250-ml. porcelain evaporating dishes. A preliminary charring treatment as described by Thiers (1957) was necessary to prevent the samples from foaming and spewing out of the dishes. Some of the excess fat was burned off by the use of low ash filter paper wicks in the case of fat-trimmings samples processed. After the samples were placed in the muffle furnace, the temperature was raised gradually and the furnace was left partly open. The samples were ignited at around 450° C. After flaming ceased, the muffle furnace door was shut, and the temperature was set at 550° C. for the night.

There is a possibility of some potassium losses during the ashing operation. Carter and Greig (1957) reported the potassium content of rat tissues decreased when dry ashing was carried out in Pyrex glass at 550° C., compared to results obtained when platinum crucibles were used. No report was made of results of ashing done in porcelain dishes.

After ashing was completed, the sulfated ash was weighed. Then a portion of ash was weighed out and formed into a briquette 1-1/8 in. in diameter, weighing about 600 mg., by the use of 15,000 lb. per sq. in. pressure applied with a hydraulic press. Similar briquettes were prepared with analytical grade potassium chloride for use as standards. The briquettes were placed in cupped stainless steel pans that were 1-1/4 in. in diameter and 3/32 in. deep. The thickness of the briquetted ash samples was such that none of them protruded above the lip of the stainless steel pans. The beta radioactivity of the ash samples was measured by the use of a commercial gas-flow counter with a very thin plastic window having a density of less than 150 micrograms per cm^2. The efficiency of the counter was checked daily with the potassium chloride standards. Counting efficiency (averaging about 31%) varied only slightly from day to day and corrections were made for these fluctuations. Each sample was counted for a total of at least 8000 counts, and the associated background for at least 200 counts, which resulted in a relative standard deviation of the sample net counting rate determination of less than 2% (Comar, 1955).

Results and Discussion

The relationship between the beta radioacivity of the ash expressed in terms of the equivalent percent of potassium in the fresh sample which would account for the amount of beta radioactivity measured, and the percent of ether extract in the fresh sample is illustrated in figure 1. The correlation between beta radioactivity and percent ether extract was highly significant (r value, —.99). The sample standard deviation from

regression (Snedecor, 1956) was 2.2% (ether extract). The 95% confidence interval for the predicted ether extract content from the beta radioactivity of the ash at the point of average beta radioactivity (0.213 units) was from 41.0 to 50.2% or 45.6±4.6% ether extract. The range of ether extract content in the 36 samples studied was from 13.0 to 78.6%. The ranges of the protein and moisture contents of these samples were from 5.2 to 21.6% and from 16.1 to 64.7%, respectively. The 95% con-

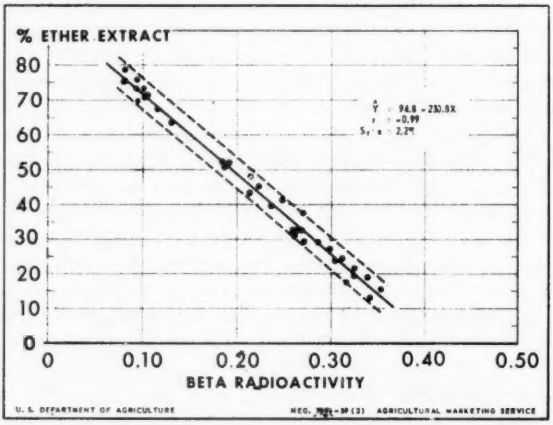

Figure 1. Regression of the percent ether extract (fresh weight basis) on the beta radioactivity of the ash (expressed in terms of the equivalent percent potassium which would account for the amount of beta radioactivity measured). The regression line is indicated by the continuous line and its 95% confidence limits by the interrupted lines.

fidence intervals of the predicted protein and moisture contents at the point of average beta radioactivity were 12.7±1.3% and 40.8±3.5%, respectively. The average beta radioactivity of 0.213 units is that amount that would be emitted by a sample containing 0.213% potassium on a fresh basis with no other radioactive ash component. With the procedures used in this study, this corresponds to a measured beta radioactivity of 117 counts per minute per 100 gm. of fresh sample containing 45.6% ether extract. The data relating to the correlations of protein and moisture with beta radioactivity are presented in figures 2 and 3.

These results indicate a relationship between the beta radioactivity emitted and the fat-free lean content of the samples analyzed. More information is needed about the variability of the amount of radioactivity emitted by the fat-free lean of different muscles in a carcass as well as the overall differences among carcasses and among live animals. In the

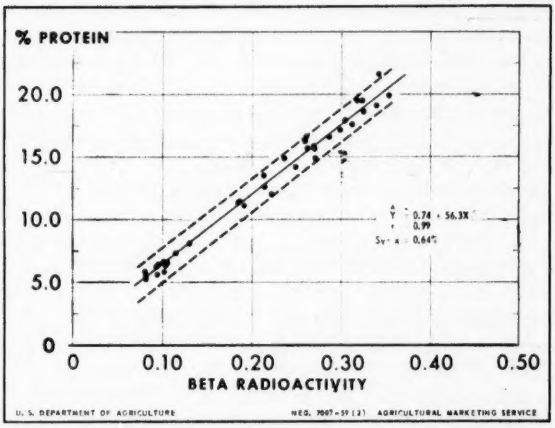

Figure 2. Regression of the percent protein (fresh weight basis) on the beta radioactivity of the ash (expressed in terms of the equivalent percent potassium which would account for the amount of beta radioactivity measured). The regression line is indicated by the continuous line and its 95% confidence limits by the interrupted lines.

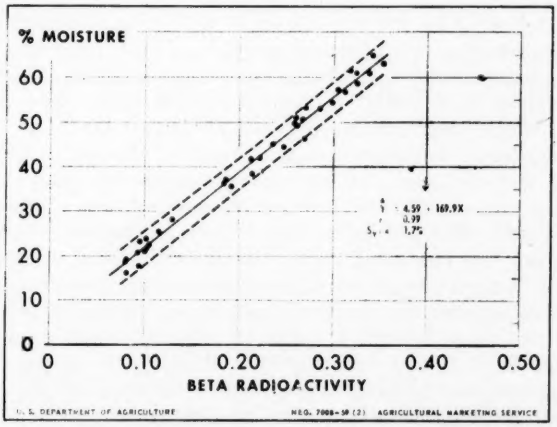

Figure 3. Regression of percent moisture (fresh weight basis) on the beta radioactivity of the ash (expressed in terms of the equivalent percent potassium which would account for the amount of beta radioactivity measured). The regression line is indicated by the continuous line and its 95% confidence limits by the interrupted lines.

present study, the average value for beta radioactivity of ash components on a fat-free fresh weight basis was 211 counts per minute per 100 gm. In making this calculation it is assumed that the fat contributes no ash components emitting beta radioactivity. On a fat-free fresh weight basis, 211 counts per minute per 100 gm. is equivalent to the beta radioactivity that would be emitted by a sample containing 0.40% potassium and no other source of beta radioactivity in the ash. The coefficient of variation of the beta radioactivity emission rate on this basis was 7.6%.

More information is needed about the gamma radioactivity emitted by meat cuts, carcasses, and live animals, since the gamma-ray measurement technique offers the possibility of making nondestructive measurements. This laboratory is planning to carry out further studies involving nondestructive gamma-ray measurements of meat samples.

A review of the pertinent literature gives other indications of the possible usefulness of potassium measurements for providing an index of the muscle mass in addition to those previously cited. Muldowney *et al.* (1957) reported that total exchangeable potassium was closely correlated with the lean body mass in a study carried out with 16 normal human males and 14 normal females ("r"=0.90). There is evidence that total exchangeable potassium may represent the bulk of total body potassium. Corsa *et al.* (1950), on the basis of a tracer study with human subjects, reported that the total exchangeable potassium content was probably 5% less than total body potassium. Rundo and Sagild (1955) reported that potassium —42 exchanges with about 85% of the body potassium —40 in humans.

Cheek and West (1955) determined the total body potassium and the lean body mass of 30 rats of various weights and ages. They reported that there was a close correlation between total body potassium and lean body mass. Holliday *et al.* (1957) determined the potassium content of thigh and back muscle samples from albino rats of different ages. They reported a difference in the potassium content at the two sites when expressed on a fat-free dry solids basis, but not when potassium was expressed on the basis of its concentration in calculated intracellular water. Briskey *et al.* (1959a) studied the potassium content of pork ham muscles which ranged from watery and pale to dry and dark in appearance. These workers reported that there were no consistent differences in potassium concentrations (expressed on a fat-free, dry weight basis). Briskey *et al.* (1959b) reported that the differences in potassium concentrations (on a fat-free, dry tissue basis) of pork ham muscles associated with varying levels of forced exercise prior to slaughter were not significant. Huth and Elkinton (1959) studied the effect of acute fasting upon the electrolyte content of the muscle of male white rats. These workers noted that chloride and chloride to sodium ratio of fat-free skeletal muscle were increased after acute fasting for 3 to 6 days. Calculations based on the assumption that the extracellular phase is equivalent to the chloride space indicated that the intracellular water, sodium, and potassium concentrations in fat-free

skeletal muscle were essentially the same in the fasted rats as in the controls. The 13 fasted rats averaged 46.6±0.60 milliequivalents of potassium per 100 gm. of fat-free solids (mean ± standard error), while the corresponding value for the 6 control rats was 46.8±1.15. These data appear to indicate that under the experimental conditions which prevailed, potassium seemed to be a rather good index of the fat-free solids content of rat skeletal muscle.

Summary

The results of a study in which measurements were made of the beta radioactivity emitted by the ash of ham fat trimmings samples and samples with variable proportions of ham lean and fat trimmings from 34 hogs are presented. There is evidence of a relationship between the amount of beta radioactivity emitted, expressed on a fresh weight basis, and the percent of fat-free lean (fresh basis). Data pertaining to the correlation of beta radioactivity and the content of ether extract, protein and moisture in these samples are presented.

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EFFECT OF A HIGH-PROTEIN HIGH-POTASSIUM RATION ON THE MINERAL METABOLISM OF LAMBS [1]

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A DISTURBANCE referred to as "wheat pasture poisoning" occurs sporadically in cattle and sheep grazing wheat in the Great Plains. Symptoms of this disturbance are similar to those of grass tetany and hypomagnesemia in which there is a lowering of the blood magnesium level (Sjollema, 1932; Redmond, 1950; Barrentine and Morrison, 1953). According to Sjollema (1932), Redmond (1950) and Sims and Crookshank (1956) blood calcium is also lowered. The etiology of such disorders which has been assumed to be associated with the forage being consumed is not clear.

Lush wheat pasture is characterized by a high protein and potassium content and low sodium. The work of Bartlett *et al.* (1954) indicated that hypomagnesemia in cows grazing certain areas in Great Britain is associated with nitrogen fertilization of the soil in those areas. Bouchaert and Oyaert (1953) reported that higher nitrogen content was the principal difference between the spring grass on farms where tetany was observed and the grass on farms where tetany was not observed. Kunkel *et al.* (1953) found that the feeding of a ration containing approximately 5% potassium resulted in a significant depression in the blood serum magnesium of ewes.

In the present study attention has been given to the effect of a high-protein, high-potassium ration on mineral metabolism of lambs.

Experimental Procedure

The experimental animals consisted of 12 western wether lambs weighing about 70 lb. The lambs were allotted at random to two groups. One group was fed a ration of normal (average for fattening rations of roughage and grain) protein and potassium content (12.8% and 1.4%, respectively) and the other a ration of high protein and potassium content (34.4% and 4.7%, respectively). The composition of the rations is shown in table 1. As shown in the table, the content of protein ($N \times 6.25$) and certain minerals in ration 2 was similar to wheat forage during lush growth.

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The lambs were started on the experimental rations February 6, 1955. Approximately 25 days were required to get the lambs to consume appreciable amounts of the rations at a constant rate. Two balance trials, each consisting of a 10-day collection period preceded by a 10-day preliminary period, were then conducted. After the first balance trial, the rations were modified slightly in an attempt more nearly to equalize them in content of certain minerals. During a 10-day adjustment period between the two

TABLE 1. AVERAGE DAILY RATIONS AND THEIR CHEMICAL COMPOSITION

Items	Trial 1		Trial 2		Wheat plant[a]
	Ration 1	Ration 2	Ration 1	Ration 2	
Ration constituent, gm.					
Alfalfa hay	198	198	234	234	
Corn	66.1	65.8	80.5	80.5	
Drackett protein[b]	11.0	125.5	13.4	153.6	
Cerelose[c]	119.7	.....	146.5	.....	
Karo syrup	40	40	40	40	
KH_2PO_4	4.7	.....	5.6	.....	
$CaCO_3$	0.3	.....	.....	.....	
$MgSO_4$	0.2	.....	.....	.....	
$KHCO_3$	.....	37.4	.....	51.6	
Dl-methionine	.....	7.3	.....	8.3	
Dry matter, %	90.68	91.42	89.21	90.52	
Percentage composition (dry matter basis)					
Crude protein	12.91	33.29	12.66	35.51	29.75
Ash	5.11	10.42	5.27	11.48	12.75
Calcium	0.704	0.642	0.639	0.593	0.40
Magnesium	0.248	0.231	0.195	0.195	0.16
Phosphorus	0.459	0.393	0.482	0.510	0.46
Potassium	1.35	4.39	1.45	5.08	4.51
Sodium	0.061	0.079	0.044	0.066	0.03

[a] Plant in lush stage of growth (Shrewsbury, 1953).
[b] Drackett Assay Protein C-1. The Drackett Products Co., Cincinnati 32, Ohio.
[c] A commercial preparation of glucose. Corn Products Refining Co., New York.

trials, feed allowance was increased. The lambs were kept in metabolism stalls similar to those described by Briggs and Gallup (1949). Techniques of the balance trials were essentially as described by Tillman *et al.* (1954). Trial 1 was started March 2 and trial 2 was started April 3.

Blood samples were taken by venous puncture prior to the start of and at intervals during the experiment.

Sodium and potassium were determined in feeds, feces, urine, and blood plasma by flame photometry, the direct method being used in the analysis of the blood plasma and the internal-standard method in the analysis of feeds and excreta. Magnesium in the plasma was determined by the method of Garner (1947), and in the feeds and excreta by a modifi-

cation of the method of Young and Gill (1951). Calcium was determined by appropriate change in the Clark and Collip (1925) modification of the Tisdall (1923) method. Plasma inorganic phosphorus was determined according to the method of Fiske and Subbarow (1925) and the phosphorus of the feeds and feces was determined by application of this method to aliquots of solutions of the ash. Nitrogen (protein) was determined by the Kjeldahl method (A.O.A.C., 1950).

Magnesium, calcium and phosphorus fecal excretion (gm. and % bases), total excretion (% basis) and balance (retention) data, and blood values for these three minerals, were treated statistically by the use of the t-test (Snedecor, 1946).

Results and Discussion

The average daily mineral and nitrogen balance data are shown in table 2.

Fecal magnesium excretion was significantly increased during both trials by the high-protein, high-potassium ration (ration No. 2). In trial 1, fecal magnesium accounted for 45% of intake for ration 1 and 66% for ration 2. In trial 2, comparable fecal magnesium percentages were 59 and 78. It appears that the high-protein, or high-potassium content of this ration either interfered with magnesium absorption or promoted re-excretion of this ion into the gut. Urinary excretion of magnesium was concomitantly decreased in both trials. Head and Rook (1955) observed a decrease in urinary magnesium excretion when cows were first allowed to graze spring grass or were administered a high level of ammonium salts. Magnesium balance on ration 2 was depressed significantly in trial 1 but the difference was not significant in trial 2.

Average fecal phosphorus excretion was slightly less on ration 2 in trial 1 and markedly less ($P<.01$) in trial 2. Thus, the higher concentration of protein and potassium in ration 2 appeared to improve phosphorus absorption or to decrease excretion into the gut. Phosphorus balance was significantly increased during both trials. This increase does not appear to be a function of intake, because in trial 1 the intake of phosphorus was actually lower for the animals receiving ration 2; and in trial 2, although it was higher, the total excretion, expressed as percent of intake, was lower ($P<.01$).

Feeding the high-protein and potassium ration (No. 2) resulted in a decrease in average fecal calcium excretion in both trials. The decrease was statistically significant ($P<.05$) only in the second trial. The result was an improvement in calcium balance which was significant in trial 1 and highly significant in trial 2.

The high protein and potassium content of ration 2 did not affect sodium balance, although it did decrease fecal sodium excretion by about 50%. This observation is of interest in relation to the reduction in fecal

TABLE 2. AVERAGE DAILY BALANCE DATA

Nutrient	Ration number	Intake	Excretion					Balance
			Fecal	Urinary	Total	Fecal	Total	
		gm.	gm.	gm.	gm.	%	%	gm.
			Trial 1					
Magnesium	1	0.984	0.441	0.465	0.906	44.8	92.1	0.078
	2	0.999	0.654*	0.333	0.987	65.5**	98.8*	0.012*
Phosphorus	1	1.81	1.65	0.30	1.94	90.4	107.0	—0.13
	2	1.70	1.30	0.43	1.73	76.8	101.2	—0.03*
Calcium	1	2.78	2.96	0.17	3.13	106.5	112.6	—0.34
	2	2.78	2.71	0.14	2.85	97.5	102.5	—0.07*
Sodium	1	0.242	0.046	0.305	0.351	....	.....	—0.109
	2	0.341	0.024	0.400	0.424	....	.....	—0.082
Potassium	1	5.35	0.43	4.77	5.20	....	.....	0.16
	2	19.04	0.31	17.51	17.82	....	.....	1.20
Nitrogen	1	8.16	2.00	6.77	8.78	....	.....	—0.62
	2	23.08	1.94	21.95	23.89	....	.....	—0.81
			Trial 2					
Magnesium	1	0.902	0.534	0.472	1.006	59.2	111.4	—0.103
	2	1.000	0.784**	0.334	1.118	78.4**	111.8	—0.118
Phosphorus	1	2.23	1.97	0.32	2.28	88.1	102.2	—0.05
	2	2.61	1.57	0.43	2.00	60.1**	76.5**	0.61**
Calcium	1	2.96	3.59	0.17	3.76	121.6	127.3	—0.80
	2	3.05	3.26*	0.14	3.40	107.0*	111.5**	—0.35**
Sodium	1	0.204	0.054	0.309	0.363	.....	.....	—0.159
	2	0.340	0.029	0.401	0.430	.....	.....	—0.090
Potassium	1	6.71	0.51	4.82	5.33	.....	.....	1.37
	2	26.04	0.37	17.54	17.91	.....	.....	8.13
Nitrogen	1	9.20	2.47	6.85	9.32	.....	.....	—0.12
	2	28.37	2.33	21.98	24.31	.....	.....	4.06

* $P<0.05$.
** $P<0.01$.

potassium excretion observed in this laboratory in lambs receiving large amounts of NaCl (Tillman and MacVicar, unpublished). There appeared to be some potassium retention by the lambs, particularly by those on ration 2.

Nitrogen balance on both rations was slightly negative in trial 1, perhaps a reflection of an inadequate intake of TDN. In trial 2 the animals

TABLE 3. BLOOD PLASMA LEVELS OF CERTAIN MINERALS (MG./100 ML.)

Mineral element	Ration	Levels on given dates[a]						
		2/4	2/11	2/16	2/21	3/18	4/2	4/18
Magnesium	1	1.98	1.90	1.80	1.89	1.60	2.70	2.59
	2	1.82	1.65	1.54	1.73	1.33	2.37	2.10
Inorganic phosphorus	1	6.31	6.66	8.08	7.14	6.18	6.07	6.02
	2	6.82	7.36	8.43	7.46	7.23	7.28	7.12
Calcium	1	7.8	8.7	7.8	8.4	8.8	9.0	9.2
	2	7.9	8.1	7.7	8.3	8.6	8.7	8.7
Sodium	1	356	357	364	351	378	355	374
	2	361	355	364	349	363	374	371
Potassium	1	19.1	20.4	19.9	20.6	18.5	17.8	17.5
	2	19.7	20.0	19.6	19.8	18.6	17.0	17.9

[a] Each value is an average from six lambs on ration 1 and five lambs on ration 2.

on ration 1 continued to be in slight negative nitrogen balance, while those on ration 2 were in positive balance.

The average blood plasma data are shown in table 3. In figure 1 are shown the changes in plasma magnesium, calcium and inorganic phosphorus.

Blood plasma magnesium levels were lower throughout both trials for the animals receiving ration 2, consistent with a lowered magnesium retention. In the second trial, the difference approached 0.5 mg./100 ml.

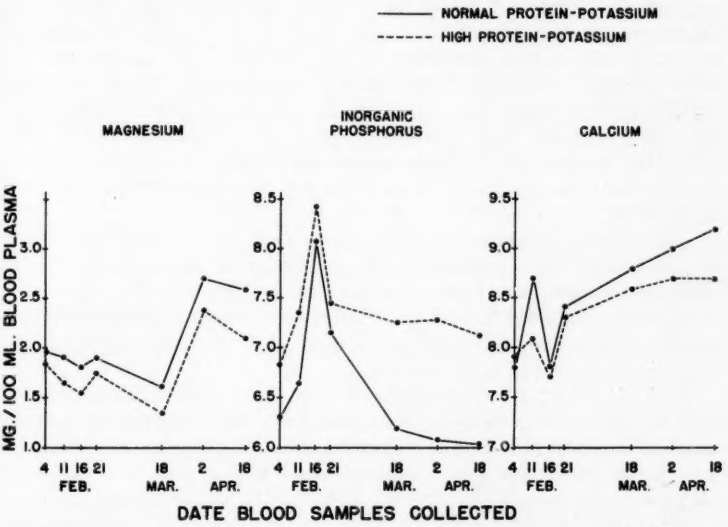

Figure 1. Magnesium, calcium and inorganic phosphorus levels in blood plasma of lambs fed a control ration and a ration high in protein and potassium.

The difference in change in plasma magnesium from the initial (February 4) to the final (April 18) level was not statistically significant. These data should be compared with the observations of Head and Rook (1955) who found that ammonium ion administration to cattle by rumen resulted in a slight depression in plasma magnesium, and with the findings of Kunkel *et al.* (1953) who observed that feeding a ration containing 5% potassium depressed plasma magnesium in ewes.

Blood plasma inorganic phosphorus levels were variable before the beginning of the balance trials, with little difference between groups. During the balance trials, however, the inorganic phosphorus level in the blood of the animals being fed ration 1 averaged more than 1 mg./100 ml. less than that of the animals receiving ration 2, despite the fact that the phosphorus content of the two rations was approximately the same. The

blood composition and the phosphorus balance data are consistent in that ration 2 was associated with a higher blood phosphorus and a higher phosphorus balance. These findings fail to corroborate the findings of Sims and Crookshank (1956) who reported a lowered blood inorganic phosphorus level in cattle exhibiting symptoms of "wheat pasture poisoning" in the High Plains area of West Texas. Barrentine and Morrison (1953) also found that serum inorganic phosphorus was lowered in lactating ewes suffering from "grass tetany" in Mississippi.

At the beginning of the experiment blood plasma calcium values were variable and somewhat below the normal range of sheep. As the test progressed the level of calcium in the blood of the animals receiving the normal-protein, normal-potassium ration increased and approached the normal range. In the animals on ration 2, however, the calcium level was consistently less during the balance trials and the difference increased as the trial progressed. The difference in the change in plasma calcium from the initial to the final level approached significance at the 5% level. A decrease in blood calcium has been frequently associated with the disorder in the field.

The sodium and potassium blood levels were within the normal range for lambs and there appeared to be no change in the concentration of either ion in the blood plasma as a result of feeding large amounts of protein and potassium. In the case of potassium it is interesting to note that although the feeding of ration No. 2 resulted in increased retention, the blood plasma level was fairly constant.

In these controlled feeding trials, evidence was obtained tending to support the view that a factor in the etiology of "wheat pasture poisoning" is an increased fecal excretion of magnesium. Although plasma magnesium was normal throughout the experiment, the tendency was for the level to be lower in the animals receiving the high-protein, high-potassium ration.

Summary

A ration of known ingredients simulating in composition that of wheat pasture (high protein and high potassium) during periods in which "wheat pasture poisoning" occurs was formulated and fed to lambs in two balance trials. This ration provides a means of approaching the problem under more controlled conditions than is possible with clinical material in the field.

In both trials, the high-protein, high-potassium ration resulted in a significant increase in fecal magnesium excretion when compared with feeding a control ration. Magnesium retention was significantly decreased in the first trial and was slightly decreased in the second by the high-protein, high-potassium ration. The increased fecal excretion of magnesium was associated with a decreased plasma level.

The findings of this study are consistent with the view that rations high

in protein or potassium may induce tetany by interfering with the absorption or retention of magnesium.

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SELECTION INDEXES FOR WEANLING TRAITS IN SPRING LAMBS [1]

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THE problem of an objective measure for selection among potential breeding animals, where more than one trait or character is to be considered, is always faced by breeders. It was shown by Hazel and Lush (1942) that selection is more effective when based on total score or index, combining and properly weighting the several traits under consideration, than it is for single traits or for several traits with independent culling levels. The development of selection indexes by Smith (1936) and Hazel (1943) provided a quantitative expression in which each of the traits affecting net merit receives proper weight.

The purpose of this study was to develop a selection index based on weanling traits of milk-fat spring lambs. Such an index was needed to select among rams being progeny tested for crossing ability on grade ewes at the Virginia Station and should be useful to breeders producing rams for use by commercial lamb producers in the farm flock states.

Selection indexes for sheep have been developed previously by Morley (1951a), Rae (1950), Ercanbrack (1952), and Karam *et al.* (1953). These were based on other than weanling traits or were concerned with breds not commonly used in the early spring lamb states and therefore might not be suitable for use in this area.

Results

Estimates of Genetic and Phenotypic Parameters. Genetic and phenotypic parameters, needed for construction of a selection index, were estimated from data obtained from the grade ewe flock at the Virginia Station. Records were available on 498 ewe and wether lambs sired by 25 Hampshire rams in eight seasons (1946–48 and 1953–57). The ewe flock consisted of grade native blackface of predominantly Hampshire breeding, crossbred western and grade Rambouillet ewes. This flock and its management are described in detail by Carter *et al.* (1957, 1958). Part of the rams used were purchased at ram sales and part were raised in the College or Station flocks. They were considered a reasonable approximation to a random sample of purebred Hampshire rams available to commercial sheepmen of this area.

The traits of concern were weight at 120 days of age, daily gain from

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TABLE 1. ESTIMATES OF CONSTANTS FOR FIXED EFFECTS FROM LEAST SQUARES ANALYSIS

Constants for	120-day weight	Daily gain birth to marketing or weaning	Market grade
Ewe minus wether	—4.7±0.9	—.037±.007	0.5±0.2
Twin minus single	—10.7±0.9	—.077±.008	—1.5±0.2
Estimate of the mean	82.7±1.1	0.572±.008	13.1±0.2

birth to marketing or weaning, and market grade at slaughter or weaning. The weights were adjusted to a standard age of 120 days by linear interpolation using two or more weights taken at 14- or 28-day intervals bracketing the 120th. day of age of the lamb. All lambs were graded as live slaughter lambs by a committee of three or more at least one of whom was an official grader of the Division of Markets of the Virginia Department of Agriculture. Standards for federal-state grading of live slaughter lambs were used and each lamb graded as being in the lower, middle or upper third of the grade. Thus the unit of grading was 1/3 of a grade. Numerical values were assigned to the grades with average or middle Good designated as 10 and the value of one (1) added or subtracted for each 1/3 of a grade above or below middle Good. The grades of the committee were averaged for each lamb to the nearest 1/10th of a grade unit (1/3 of a grade).

The effects of sex (ewe or wether), type of rearing (single or twin), and year of birth were assumed to be fixed. Constants for these effects were estimated by conventional least square methods. Table 1 shows the estimated constants with their standard errors for sex and type of rearing. These are consistent with estimates previously obtained at the Virginia Station (Kincaid and Carter, 1953; Hundley and Carter, 1956; Carter *et al.*, 1957, 1958). The data were adjusted to a single wether lamb born in 1953 by these constants. Phenotypic and genetic variances and covariances calculated from the adjusted data are shown in table 2.

Phenotypic correlations among the traits studied were obtained by the product-moment method. Genetic correlations were estimated, the sire components of variance and covariance being used as described by Hazel

TABLE 2. GENETIC AND PHENOTYPIC VARIANCES AND COVARIANCES

Item		120-day weight	Daily gain	Market grade
120-day weight	Gen.	6.9656	0.0988	0.6600
	Phen.	103.3914	0.7184	11.015
Daily gain	Gen.	.....	0.001212	0.0096
	Phen.	.....	0.006713	0.0977
Market grade	Gen.	.....	.....	0.4960
	Phen.	.....	.....	4.0740

TABLE 3. GENETIC AND PHENOTYPIC CORRELATIONS

Item		Daily gain	Market grade
120-day weight	Gen.	1.08	0.36
	Phen.	0.86	0.54
Daily gain	Gen.	....	0.39
	Phen.	....	0.59

et al. (1943). These correlations are shown in table 3. The phenotypic correlation between daily gain and market grade (.59) is somewhat larger than that (.46) reported by Hundley and Carter (1956). The genetic correlation between 120-day weight and daily gain, 1.08, is obviously too large, but does indicate that the two are measuring essentially the same effects. Genetic correlations among the traits studied have not been reported previously.

Heritability of the various traits, estimated from paternal half-sib correlations, are shown in table 4. The estimates of heritability of 120-day weight (.07) and of daily gain (.18) are in the lower portion of the range of similar estimates published by other investigators. Heritability of weaning weight has been reported as 0.30 by Hazel and Terrill (1945b); 0.35 by Karam *et al.* (1953); 0.36 by Morley (1951b); 0.41, 0.27, and 0.77 by Warwick and Cartwright (1957). Other reports more nearly in agreement with those found in the present study include 0.17 (Hazel and Terrill, 1945b); 0.073 (Blackwell and Henderson, 1955); and 0.145 (Felts *et al.*, 1957). Hundley and Carter (1956) estimated heritability of daily gain in grade Hampshire lambs to be 0.38 but only 0.04 for grade Southdowns. They also reported heritability of market grade at 0.28, somewhat higher than the 0.12 found here. No other estimates of heritability of market or slaughter grade have been reported. However, Hazel and Terrill (1945a, b) reported heritability of condition score and body type to be low in the Rambouillet, Columbia, and Targhee breeds.

Relative Economic Values. Relative economic values were estimated from data obtained from the Daily Market Reports of the Virginia Department of Agriculture. These included weekly prices of lambs by official grades for the five months of the spring lamb marketing season (May through September) from 23 Virginia Livestock Auction Markets. These

TABLE 4. SIRE COMPONENTS, k VALUES,[a] HERITABILITY ESTIMATES AND STANDARD ERRORS

Character	Sire component	k value[a]	Heritability	Standard error
120-day weight	1.7414	19.68	0.067	0.015
Daily gain	0.000303	19.68	0.181	0.021
Market grade	0.124	19.68	0.122	0.018

[a] k=number offspring per sire.

data had been previously assembled and summarized by Johnson (1958) and were made available to the authors.

The average price per hundredweight for all lambs sold on these markets over the five years was $22.40. This was rounded to 22 cents per pound and used as the value of the increase of one pound of liveweight at 120 days. The value of an increase of a full market grade was estimated at $3.02. This amount represents the average difference in value of lambs in adjacent grades (Prime minus Choice, Choice minus Good, etc.) weighted by the proportion of lambs in each of the four lower grades. Since 1/3 of a grade was the unit of grade measurement the value of $1.00 was used for changes of 1/3 grade.

TABLE 5. SELECTION INDEXES USING VARIOUS COMBINATIONS OF THE TRAITS STUDIED

	b values for index				Expected genetic change per standard deviation in index		
Index no.	120-day weight	Daily gain	Market grade	R_{IH}	120-day weight	Daily gain	Market grade
1	0.0062	.....	0.1405	0.30	0.42	0.006	0.23
2	.....	4.4353	0.0160	0.36	1.17	0.014	0.13
3	1.0000	.....	.....	0.20	0.68	0.010	0.06
4	.....	1.0000	.....	0.36	1.21	0.015	0.12
5	.....	.....	1.0000	0.30	0.33	0.005	0.25

Selection Indexes. A selection index may be defined as a linear function of the observed characters, X_i, which has a maximum correlation with the aggregate genetic value of the individual. The aggregate genetic value of an animal is defined as the sum of its genotypes for the several traits involved, each genotype being weighted according to the relative economic value of that trait. It may be expressed as:

$$H=a_1G_1+a_2G_2 \ldots\ldots\ldots\ldots\ldots +a_nG_n$$

Here the a_i are the relative economic values and the G_i are the expected values of the X_i due to additive genetic effects. The index is expressed as:

$$I=b_1X_1+b_2X_2+ \ldots\ldots\ldots\ldots\ldots b_nX_n$$

Here the X_i are the observed phenotypic values of the traits and the b_i are the partial regression coefficients that will maximize the correlation, R_{IH}, between the index and the aggregate genetic value of the individual.

Five selection indexes for different combinations of the three traits studied were calculated using the parameters estimated in this study and the multiple correlation method (Hazel, 1943). The partial regression coefficients (b values), the correlations between the indexes and the aggregate genetic values (R_{IH}), and the expected genetic change per unit change of index (in standard measure) are shown in table 5.

Since daily gain has no economic value as such, it was used as a prediction for 120-day weight and market grade. Therefore, the indexes, including daily gain, were calculated using only the economic values of 120-day weight and market grade for the aggregate genetic values. This procedure permitted the use of daily gain as a selection criterion.

Discussion

The highest correlation between the index and aggregate genetic value (R_{IH}) was 0.36 for indexes 2 and 4. Index number 4 is based on daily gain alone while index number 2 is based on daily gain and market grade. Before the estimates of heritability and genetic correlations were obtained it appeared, on intuitive grounds, that a combination of market grade with daily gain or with 120-day weight would be a logical basis for a selection index for weanling lambs. However, indexes 1 and 2, which are based on these combinations, are not superior in the correlation between I and H to an index based on daily gain alone. If the estimates of genetic and phenotypic parameters and economic values found in this study are accepted, one can conclude that selection for daily gain alone will result in near maximum economic gain. As a result of this study, index number 4 based on average daily gain is presently being used in selection among progeny tested rams at the Virginia Station.

The economic data used in this study are considered quite reliable. They are based on accurate records of sales of a large number of lambs (165,000 in 1956 alone) over a five-year period at 23 auction markets. All were uniformally graded by official graders of the State Division of Markets. It is doubtful if more useful economic data for the purpose are available.

The genetic and phenotypic parameters are based on only a moderate amount of data. The heritability estimates are generally lower than the average of those reported by other investigators. Most of the others reported, however, have been based on breeds of fine wool or Merino derivation. It has been suggested that heritability, particularly of growth rate, may be lower in mutton or down breeds than in the fine wool breeds. The need for additional independent estimates of genetic parameters in mutton breeds of sheep seems evident.

The indexes developed in this study are considered applicable to market lambs sired by Hampshire rams and produced in the spring lamb areas of Virginia and adjacent areas with similar conditions. They may or may not be applicable to other areas or breeds.

Summary

Five selection indexes for early milk-fat spring lambs were developed and compared. These were based on the weanling traits, daily gain from birth to weaning or slaughter, 120-day weight, and live market grade.

Selection on daily gain alone seems most practical because it is easiest to use and should give near maximum genetic returns in economic terms. Estimates of heritabilities, genetic and phenotypic correlations, and economic values were calculated.

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EXCRETION STUDIES IN SWINE FED ARSANILIC ACID

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Russo, Hanson and Jezeski (1954) studied the effects of short term arsanilic acid feeding on nitrogen retention in young pigs. During that study these workers sent us excreta samples for a separate investigation of arsenic balance. Nitrogen balance was the primary objective of the Minnesota experiment. The cooperation afforded an opportunity for us to study the rate and, in part, the form of arsenic excretion following arsanilic acid feeding in pigs.

Experimental

The experimental design and methods for collecting excreta have been given by Russo (1954). The general procedures were as follows. Pigs weighing 50–75 lb. were placed in individual metabolism cages and fed a basal ration composed of 83.6% corn, 6% soybean oil meal, 2.6% tankage, 1.3% linseed oil meal, 5% dehydrated alfalfa meal, 1.0% steamed bone meal and 0.5% trace element salts. Vitamins were added to each 100 lb. as follows: 100 mg. riboflavin, 450 mg. niacin, 200 mg. pantothenic acid, 0.5 mg. vitamin B-12, 500 mg. choline, and 10 gm. irradiated yeast. Each pig received 5 lb. of ration per 100 lb. body weight per day.

Arsenical excretion was studied in two experiments. In each, single barrows received 0, 30, 60 and 90 gm. of arsanilic acid per ton of feed. In Series I, trial 2, the pigs were on the test ration for 12 days. Daily excreta were collected for the 11th and 12th days and then all four animals were given the control ration without arsanilic acid. Excreta were then collected for 3 "post arsanilic acid feeding" days. In Series II, pigs were fed the rations with arsanilic acid for 30 days and then placed on the control ration without arsanilic acid. Daily excreta collections were made only for 12 "post arsanilic acid feeding" days.

Excreta were treated with a trace of toluene and fresh frozen. Appropriate aliquots were sent by express from St. Paul to North Chicago. Arsenic analyses were made on the urine and feces by the method of Evans and Bandemer (1954). Five grams of feces were ashed with 8 cc. of saturated magnesium nitrate solution. The ash was dissolved in 10 cc. of concentrated hydrochloric acid and diluted to 100 cc. Suitable aliquots were then analyzed colorimetrically for arsenic concentration. For the urine analyses, 25 cc. of urine were evaporated to dryness on the steam bath with 4 cc. of

[1] The authors are grateful to L. E. Hanson, J. M. Russo and J. J. Jezeski, University of Minnesota, for supplying us materials from their experiments which made this study possible.
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saturated magnesium nitrate solution. The residue was ashed and analyzed for arsenic. Analytically pure arsanilic acid was used as a standard and results were *calculated* as elemental arsenic.[3]

Arsanilic acid was determined by a modification of the method for arsanilic acid in feeds (A.O.A.C., 1954). The feces samples were extracted with water. Aliquots were analyzed directly for arsanilic acid. Urine samples were analyzed directly without dilution. The urine samples, both from the control pigs and those fed arsanilic acid, produced only slight color

TABLE 1. ARSENIC EXCRETION BY PIGS DURING AND AFTER THREE LEVELS OF ARSANILIC ACID FEEDING

Arsanilic acid in ration	Period[a]	Average daily arsenic intake	Av. daily total arsenic voided		Av. daily arsenic voided as arsanilic acid	
			Feces	Urine	Feces	Urine
gm./ton		mg.	mg.	mg.	mg.	mg.
0	..	0	0.1	0.1	0	0
30	1	16.1	12.2	2.2	0.2	0
	2	0	9.9	1.8	1.4	0
60	1	21.1	12.3	10.5	1.0	0
	2	0	14.1	5.8	0.5	0
90	1	49.2	22.3	14.4	2.8	0
	2	0	35.7	11.5	2.6	0

[a] Period 1=Last two days of 12-day arsanilic acid feeding; Period 2=First three days post-arsanilic acid feeding.

following the diazotization and coupling reactions, indicating little or no free arsanilic acid excreted in the urine. No increase in color was obtained following hydrochloric acid treatment of the urine. This indicated that arsanilic acid was not excreted in acetylated or other readily hydrolyzed form.

Results

Series I, Trial 2. The averaged excretion for the last two days of arsanilic acid feeding and the three "post arsanilic acid" days are shown in table 1. For the last two days of arsanilic acid feeding total arsenic excretion was roughly proportional to intake, exceeding the intake at the 60 gm./ton level, slightly below the intake at the 30 gm. level and about 70% of the intake at the 90 gm. level. The excretion continued at near these levels in the three-day period after arsanilic acid was removed from the ration.

[3] The form of the arsenical in tissue and excreta is not precisely known. Confusion exists because of the indiscriminate use of such terms as, "arsenic in tissue", "the level of As_2O_3", etc. The implication is that inorganic arsenic or even elemental arsenic is present in biological systems. Much evidence indicates that arsenic in animal systems is organically bound. In the present experiments, reporting the amounts of "arsenic" does not imply that inorganic arsenic was fed or excreted.

Arsanilic acid was not detected in the urine. Of the total arsenic voided in the feces only 5–10% was as arsanilic acid. The major route of arsenical excretion was through the feces, rather than the urine.

Series II. This experiment showed the continuing rate of excretion up to 12 days following withdrawal of arsanilic acid from the feed. Results for the first six days and alternate days thereafter are shown in table 2 for

TABLE 2. RATE OF DISAPPEARANCE OF ARSENIC FROM EXCRETA AFTER 30-DAY ARSANILIC ACID FEEDING

	Av. daily excretion of arsenic at two arsanilic acid feed levels			
	Feces		Urine	
Days after arsenical withdrawal	30 gm./ ton level[a]	90 gm./ ton level[b]	30 gm./ ton level	90 gm./ ton level
	mg.	mg.	mg.	mg.
1	7.6	19.4	1.9	6.5
2	7.0	29.6	1.3	4.0
3	5.9	7.5	0.9	2.7
4	0.8	1.8	1.1	2.8
5	0.2	1.3	0.5	1.5
6	0.6	0.6	0.5	0.7
8	0.4	0.6	0.6	1.2
10	0.1	0.2	0.5	0.5
12	0.1	0.1	0.3	0.5

[a] Average intake of arsanilic acid equal to 18 mg. As per day for 30 days.
[b] Average intake of arsanilic acid equal to 64 mg. As per day for 30 days.

animals that had received arsanilic acid at the 30- and 90-gm. per ton level. There was an abrupt decrease in amount excreted at 3 to 4 days. This had reached a very low value at the 12th day.

Discussion

Deposition of arsenic in tissues of chickens and turkeys has been shown to be related to the level and nature of the arsenical fed (Frost, Overby and Spruth, 1955). Deposition was proportional to the level of arsanilic acid fed to chickens (Frost, 1953) and swine (Hanson, Carpenter, Aunan and Ferrin, 1955). These studies also showed that disappearance from tissues was rapid, the major amount being lost in 2 days after removal of arsanilic acid from the ration. At a constant feeding level of arsanilic acid, a plateau in level of arsenic in the muscle, liver and bone of chickens was reached within two weeks (Frost, 1953).

In studies with man, Lockemann (1916) reported that injection of 0.5 gm. sodium arsanilate led to urinary excretion of 50% of the injected dose in 3 hours and 88% in 12 hours. In studies with swine, Carpenter (1951–52) determined the blood levels which resulted from feeding 0.02% of three

different arsonic acids in the diet. Arsanilic acid, the best tolerated of the three, produced the highest level of arsenic in the blood. Conversely, 3-nitro-4-hydroxyphenylarsonic acid, the least tolerated of the three, gave the lowest blood levels. As discussed by Frost *et al.* (1955), toxicity of the different arsonic acids appears to be related to the amount of arsenic retained, particularly in the liver. This in turn is apparently related to the way in which the body metabolizes and excrets the arsenical.

Obviously there are wide gaps in our knowledge on these points. The present study helps to fill in one of these gaps, supplying evidence that dietary arsanilic acid is largely catabolized. Only about 5% or less of the arsanilic acid ingested is recovered as such.

The fact that much more of the total arsenic fed is excreted in feces than in the urine came as a surprise. Our thinking here was based on the report by Lockemann (1916) of the almost quantitative urinary excretion of the arsenic of arsanilate injected in man. Several variables could account for this difference, such as the different modes of administration, the wide difference in dose, the difference in mechanism by which the body would handle a single massive dose versus small repeated doses, and difference in species. It is quite possible that arsanilic acid, like certain antibiotics, was excreted through the bile under the conditions of our experiments. Possibly much of the arsanilic acid was not absorbed.

The data of table 2 show that of the total amount of arsenic excreted a large proportion is voided in 3 days following removal of arsanilic acid from the feed. This agrees with the studies of Hanson *et al.* (1955) showing that disappearance of arsenic from tissues was rapid.

Summary

The rates of arsenic excretion were determined in the feces and urine of swine receiving arsanilic acid at 30, 60 and 90 gm. per ton of feed. Much more arsenic was excreted in the feces than in the urine. After 10 days of arsanilic acid feeding, total excretion was in approximate balance with intake at the two lower levels of feeding. After the arsenical was withdrawn from the ration, the characteristic excretion level continued for two days, then decreased rapidly. This conforms with knowledge of the rate of disappearance of arsenic from tissues of animals fed arsanilic acid. The nature of the major part of the arsenical excreted was not determined. Unchanged arsanilic acid was not detected in the urine, but was present in the feces in an amount representing about 5% of the arsanilic acid consumed.

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PORK QUALITY II. PHYSICAL, CHEMICAL AND ORGANOLEPTIC RELATIONSHIPS IN FRESH PORK

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THIS investigation was conducted to ascertain the relationships existing between certain observed characteristics and some processing and palatability factors in pork.

Materials and Methods

Fifty-four fresh pork loins from Ohio Swine Evaluation Station hogs were classified subjectively on the bases of the color, marbling, and firmness of the *Longissimus dorsi* muscle. Visual appraisal was made of the cross sectional surface of the muscle at the 10th rib. Classification was made about 48 hours post mortem; internal temperatures were about 36° F.

Greyish-pink color was the standard. Deviations from this standard were recorded as "light" or "dark". The amount of intramuscular fat seen at the 10th rib section was recorded as "slight", "moderate", or "abundant". The firmness of the loins was recorded as "soft", "intermediate", or "firm".

Some chemical analyses were performed about 54 hours post mortem. Samples of the *Longissimus dorsi* muscles were taken from the 8th-10th rib areas of the loins, freed of all external connective tissue and fat, and ground in an attachment to a Hobart Kitchen-Aid food mixer. Moisture content of the tissue was determined by oven drying 5-gm. samples at 100–105° C. to constant weight. Water-holding properties of the muscles were determined with centrifuge tubes developed by Wierbicki *et al.* (1957). The amount of juice obtained upon heating at 70° C. for 30 min. and centrifugation at 170 times gravity for 10 min. provided the basis for calculation of the juice lost as a per cent of the total moisture. A correction factor of 0.951 gm. of water per ml. of juice was recommended by Wierbicki *et al.* (1957) for beef. The usefulness of this factor was verified for pork. The following formula was used:

$$\text{Juice lost as percent of total moisture} = \frac{\text{Ml. of juice expressed per 100 gm. sample} \times \text{0.951 gm. water per ml. juice}}{\text{Percent moisture}} \times 100$$

Modified Babcock bottles were used in the manner described by Wierbicki *et al.* (1955) to determine the fat content of the loin muscles. The

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TABLE 1. MEANS AND STANDARD DEVIATIONS OF CHEMICAL ANALYSES AND ORGANOLEPTIC DATA

Item	Mean	Standard deviation ±
Moisture, %	73.28	1.33
Juice lost as percent of total moisture	45.64	3.43
Fat, %	3.72	1.79
pH	5.55	0.13
Tenderness	6.77	0.96
Juiciness	6.63	0.50
Flavor	6.72	0.49

fat was freed by heating the samples in a protein-digesting solution and centrifuging. pH was determined with a Model DU Beckman pH meter.

Mate loins of those chemically analyzed were scored by taste panel approximately 72 hours post mortem. Loin sections from the 8th-14th rib areas were cut into chops ¾ in. thick. The chops were broiled to a medium degree of doneness; duplicate samples were scored for tenderness, juiciness, and flavor by a six-member laboratory taste panel. Tenderness and juiciness were scored on a 1 to 10 scale as described by Deatherage and Reiman (1946). Flavor was scored on the Hedonic scale proposed by Peryam (1956). Membership on the panel was determined by the ability of the individual to score duplicate samples within 2 points.

The data were statistically analyzed according to the correlation and multiple linear regression methods of Ostle (1956). Adaptation of muscle classification data to correlation analyses required the numerical coding of the various muscle types.

Results and Discussion

Means and standard deviations of the chemical analyses performed and the organoleptic properties scored are in table 1. These figures indicate the variation in the samples.

TABLE 2. CORRELATION COEFFICIENTS OF PHYSICAL, CHEMICAL, AND ORGANOLEPTIC CHARACTERISTICS

Item	Moisture	Juice lost as % moisture	fat percent	pH	Tenderness	Juiciness	Flavor
Color	+.19	−.50**	−.04	+.52**	−.30*	−.25	−.16
Marbling	−.62**	−.27*	+.76**	+.20	−.07	+.40**	+.13
Firmness	−.20	−.47**	+.37**	+.65**	−.55**	−.06	−.12
Moisture percentage		+.21	−.84**	−.04	+.05	−.21	+.07
Juice lost as percent of moist.			−.12	−.62**	+.39**	+.03	+.32*
Fat percentage				+.02	−.03	+.13	+.10
pH					−.66**	−.36*	−.30*
Tenderness						+.46**	+.60**
Juiciness							+.46**

** $P<.01$.
* $P<.05$.

Correlation coefficients were calculated between all physical, chemical, and organoleptic data. (table 2). As muscle color varied from light through greyish-pink to dark, the juice lost upon heating and centrifugation decreased (—.50), and pH increased (0.52). In the same direction, as loins were more firm, the amount of juice lost was decreased (—.47) and pH was increased (0.65). The highly significant relationship between firmness and fat content was probably a result of the firmness-marbling association as reported previously (Judge *et al.* 1959). It follows that pH and the amount of juice lost would be negatively correlated (—.62). These data indicate that dark, firm loin eye muscles had greater water holding capacity and higher pH than lighter colored, softer muscles. Water holding capacity and pH were positively related. These findings are in line with those of Briskey *et al.* (1957), Hamm (1953) and Ludvigsen (1954).

The explanations for these relationships have been established by other workers. The research of Gibbons and Rose (1950) has shown that muscle glycogen stores at the time of death of the animal determine the amount of lactic acid formed upon chilling of the carcass. Lactic acid content was found to be highly correlated with pH. In 1953, Hamm pointed out that water holding capacity varied as pH varied from the isoelectric point of the protein body. He reported that electrostatic attraction by basic or acidic amino acids on polypeptide chains resulted in hydration of the tissue. When the differently charged polypeptide chains neutralized each other, the isoelectric point was reached and the amount of bound water was at a minimum. In addition, the degree of hydration affected the compactness of the peptide chains. Light penetration was thus influenced and the colors seen were dependent upon the amount of light reflected.

Table 2 also reveals the relationships found between the degree of marbling in the muscle and the chemical fat content (0.76), and between marbling and moisture content (—.62). Thus the correlation between percent fat and percent moisture (—.84) is logical. From these statistics it appears that the degree of marbling in pork, as judged subjectively, is a measure of the actual fat content of the muscle.

Tenderness, juiciness, and flavor were all correlated (table 2). In addition, tenderness was related to a greater number of the items studied than was juiciness or flavor. The large standard deviation computed for tenderness as compared with that for juiciness or flavor (table 1) suggests that tenderness was either scored more accurately or was a more variable palatability factor. These findings are compatible with the survey conducted by Deatherage (1951).

The only highly significant relationship found for juiciness or flavor was the 0.40 coefficient calculated between marbling and juiciness. This result is discounted somewhat due to the lack of significance in the correlation between chemical fat content and juiciness. Because of these questionable results and the lack of confidence expressed in the ability of the taste

panel to score juiciness and flavor accurately, few conclusions can be drawn pertaining to these two palatability factors.

As shown in table 2, four factors were found to be related to tenderness, color (—.30), firmness (—.55), juice lost as a percent of total moisture (0.39), and pH (—.66). Before conclusions can be made, however, the independent variation in these four factors that was associated with tenderness should be separated from the variation that was present between factors. A multiple regression technique was employed to calculate partial and standard partial regression coefficients. The values of "t" in table 3

TABLE 3. MULTIPLE REGRESSION STATISTICS FOR TENDERNESS AND FOUR ASSOCIATED CHARACTERISTICS

Characteristic	Partial regression coefficient	S.D. of partial regression coefficient	"t" value	Standard partial regression coefficient
Color	0.25	0.19	1.31	0.18
Firmness	—.33	0.16	2.04*	—.31
Juice lost as percent of moist.	—.01	0.04	0.17	—.02
pH	—4.05	1.14	3.57**	—.55

** $P<.01$.
* $P<.05$.

suggest that two factors, namely, firmness and pH, were related to tenderness at the 5 and 1% levels, respectively. The standard partial regression coefficients permit the direct comparison of the influence of the four characteristics as well as the observation of their direction of influence on tenderness. Water binding ability and muscle color, then, were related in simple correlation to tenderness merely as a result of their association with firmness or pH.

Explanations for the significant relationships found in these data as physical, chemical, or other phenomena are not apparent. It should be borne in mind that these regression analyses have measured degrees of association and not causes or effects.

Summary

Chemical analyses and sensory scoring of 54 pork loins shed some light on the inherent properties of individual muscle types. Dark, firm muscle was higher in pH and lower in free water than was light, soft muscle. Highly marbled muscles were higher in chemical fat content and lower in moisture than were muscles that lacked marbling.

Greater confidence was expressed in the panel scoring of tenderness than juiciness or flavor. Tenderness increased as loins became less firm ($P<.05$) and as pH decreased ($P<.01$).

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MILK PRODUCTION OF SOWS

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THE weight of pigs at weaning is quite variable from litter to litter, and much of this variation is due to the quantity of milk produced by the sows. Thus, those factors which cause a variation in milk production must also influence litter weights. Age was found to have an important influence on the amount of milk produced by sows in studies by Schmidt and Lauprecht (1926), Wells, Beeson and Brady (1940), and Berge and Indreb (1953). In general, sows suckling their third and fourth litters produced the largest amount of milk.

The most productive period of the lactation interval in sows is between the third and fifth week (Hughes and Hart, 1935; Greenslade, 1952; Smith, 1952b; Kovacs, 1954; Lalevic, 1953). This fact fits very well with the needs of the pigs. During the late part of the suckling period the pigs need less milk because they are large enough to obtain most of their required nutrients from a supplemental creep ration or by eating some of the feed fed to the sows.

The importance of milk production in sows led to this study to determine the amount of milk produced by sows and its relation to performance and to determine some of the important factors affecting milk production in sows of different breeds and crosses.

Experimental Procedure

Milk production was measured in four different seasons in a total of 50 sows from the Duroc, Poland and Landrace inbred lines and in the Landrace x Poland crossbred sows maintained in the swine breeding herd at the University of Missouri. Sows and their litters were confined to dry lot pens during the entire lactation period. The sows were handfed a well balanced ration during the lactation period, and the pigs received a creep ration beginning about the 14th day of age.

Milk production by each sow was measured once each week during a 6-week lactation period. The pigs were separated from the sow early in the morning of the day that milk production was measured. They were returned to the sow 1 hour later and permitted to nurse. No weights were taken at this time. After the pigs suckled, they were again separated from

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the sow for 2 hours after which they were weighed, allowed to nurse, and then weighed again. Their weight gain was assumed to be the amount of milk produced by the sow. Milk production was measured in this manner for a total of four successive 2-hour periods or during an interval of 8 hours. It is not known if the amount of milk produced in this 8-hour period is comparable to that produced while the pigs were on test, but the results from the same sows and litters at different test periods were consistent. Under the conditions of this experiment it was not possible to obtain milk production figures over the entire 24-hour period during lactation.

Adjustment of the sows and their litters to the unusual conditions of the experiments was generally very good. Errors caused by the pigs urinating were eliminated by moving them, before they were weighed and returned to the sows, to the area of the pen where they normally urinated. The amount of weight lost by urination was small; it varied from 0.02 to 0.07 lb., depending upon the size of the pigs. Defecation caused a very slight loss in weight, usually less than 0.01 lb.

Results and Discussion

The average amount of milk produced by sows of the different lines and crosses together with the average size of the litters suckled and the average weight of the litters at 6 weeks is shown in table 1. A highly significant breed difference ($P<.01$) was found in the amount of milk produced and in the average size of the litter suckled, whereas a significant difference ($P<.05$) was found in the average litter weight at the end of the suckling period. Landrace sows produced the most milk followed by the crossbred Landrace x Poland sows. The Duroc sows gave the smallest amount of milk with an average production of 236.2 lb. during the lactation period of 6 weeks. In general, line and cross differences in milk production were accompanied by lighter litter weights of pigs at weaning.

Milk production in sows in this study was very similar to that reported by other workers who have found average values for an 8-week lactation period ranging from 367 to 701 lb. (Hempel, 1928; Berge and Indreb, 1953; Schmidt and Lauprecht, 1926; Schneider, 1934). Smith (1952b) in a summary of data from various experiments also found an indication of significant breed differences in the amount of milk produced by sows.

In most investigations reported to date, milk production has been estimated by making weekly checks during the lactation period. Most workers have weighed the pigs before and after suckling and have considered the gain in weight as the amount of milk produced by the sows. The interval of time for separating pigs from the sows has ranged from periods of 1 hour (Oloffson and Larsson, 1930) to 5 hours (Donald, 1937). In general, investigators have found that shorter suckling intervals have resulted

TABLE 1. AVERAGE MILK PRODUCTION BY SOWS OF DIFFERENT LINES AND CROSSES DURING A 6-WEEK LACTATION PERIOD

Line or cross	No. of sows	Milk production, lb.**	Litter size during lactation period, no.**	Litter weight at 6 weeks, lb.*
Durocs	19	236.2 (50.1)[a]	7.3 (1.2)	136 (29.7)
Landrace	14	306.2 (44.3)	7.8 (1.0)	172 (41.8)
Poland	8	265.9 (51.3)	6.6 (1.1)	126 (44.4)
Landrace x Poland	9	300.0 (55.8)	9.3 (1.4)	157 (27.4)

* Breed differences were significant ($P<.05$).
** Breed differences were highly significant ($P<.01$).
[a] The figure in parenthesis is the standard deviation of the mean.

in greater milk production. Donald (1937) found that milk production during the night was about the same as during the day. Smith (1952b) in summarizing data of various workers found that the average interval between nursings when pigs were not molested ranged between 60 and 72 minutes early in the lactation period. In consideration of these factors, it is probable that in this experiment the amount of milk estimated per sow was lower than the actual amount produced under natural conditions.

The average milk production per sow during the different weeks of the present investigation is shown in table 2. The average weekly production per sow varied from a low of 33.3 lb. in Durocs during the first week of lactation to a high of 57.8 lb. in the crossbred sows during the third week. Milk production by sows was usually lowest during the first week of lactation and highest at the third to fifth week.

The average weekly milk production per pig by sows of the various breeds and crosses is shown in figure 1. The Durocs and the Landrace x Poland crossbred sows reached a peak in milk production in the third week of lactation, the Polands in the fourth week, and the Landrace in the fifth week. Apparently the Landrace sows were more persistent in a high level of milk production which was responsible for their greater total milk production during the 6-week lactation period.

The coefficients of correlation between total milk production and

TABLE 2. AVERAGE POUNDS OF MILK PRODUCED PER WEEK BY SOWS OF VARIOUS LINES AND CROSSES

Week number	Durocs	Landrace	Poland	Landrace x Poland
1	33.2 (14.4)[a]	43.4 (13.8)	41.9 (11.4)	41.2 (13.2)
2	37.8 (14.3)	50.3 (10.4)	43.0 (6.4)	57.1 (17.7)
3	50.6 (18.1)	53.2 (11.3)	48.4 (17.4)	57.8 (10.7)
4	40.8 (15.8)	56.1 (14.6)	52.6 (14.8)	51.0 (9.8)
5	39.7 (15.3)	57.1 (17.0)	40.9 (12.8)	46.1 (7.6)
6	35.4 (10.2)	45.9 (10.3)	39.0 (13.4)	45.0 (20.3)

[a] The figure in parenthesis is the standard deviation of the mean.

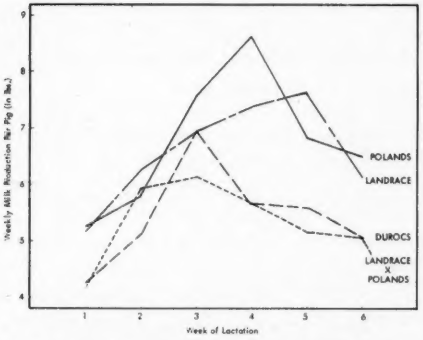

Figure 1. Showing the average weekly milk production per pig by sows of different breeds and crosses.

various other factors are shown in table 3. The age of the sows at farrowing was not significantly correlated with total milk production. A highly significant correlation ($P<.01$) existed between milk production and the size of the litter suckled. Other workers have made similar observations (Schmidt and Lauprecht, 1926; Wells, Beeson and Brady, 1940; Kovacs, 1954). One would expect this correlation to be large and positive because when more pigs are suckled, more nipples are functional.

The litter weight at weaning was significantly correlated with milk production ($P<.001$), with the sows producing the most milk weaning the heaviest litters. It was also noted that the pigs of sows which produced

TABLE 3. COEFFICIENTS OF CORRELATION BETWEEN TOTAL MILK PRODUCTION AND SOME OTHER TRAITS IN SWINE

Comparisons	All breeds and crosses	Between breeds and crosses	Within breeds and crosses
Degrees of freedom	49	3	46
Between total milk production and:			
Average size of litter suckled	0.45***	0.59	0.38**
Total weight change in sows	—.58***	—.92	—.46***
Age of the sow	0.16	0.49	—.01
Weight of the sow at farrowing	0.10	—.23	0.19
Creep feed consumed by pigs	0.45**	0.97*	0.26
Litter weight at weaning	0.58***	0.80	0.51***
Weight of sow at 154 days of age	—.24	—.68	0.02
Backfat thickness in sows when they weighed 200 lb.	—.46***	—.99***	—.07

* Probability of chance occurrence less than .05.
** Probability of chance occurrence less than .01.
*** Probability of chance occurrence less than .001.

the most milk also consumed greater amounts of creep feed. The results indicated that this was more of a breed than an individual characteristic, however, since the gross correlation was highly significant ($P<.01$) but the within breed correlation was not.

Sows which gave the most milk also lost the most weight during the lactation period. The gross coefficients of correlation as well as those within the breeds and crosses were very highly significant ($P<.001$). Downey (1951) and Burger (1952) found that sows which were suckling large litters and were milking well lost weight even under the best conditions of management with unlimited quantities of feed. Thus, weight gains or losses by sows would seem to be a good indicator of their productiveness.

Data on 154-day weights and backfat thickness were available for all sows used in the milk production study. No significant correlation was found between rate of gain in gilts and the amount of milk they produced later during lactation. The gross and between breed correlation coefficients between these two variables were negative but rather low, and the within breed correlation coefficient was practically zero. Evidence was obtained, however, that gilts with the thickest backfat produced the smallest amount of milk. The gross correlation coefficient was very highly significant ($P<.001$) as was the between breed and cross correlation, but not the within breed correlation. This suggests that the gilts from the breeds that were the fattest at 200 lb. gave the smallest amount of milk, but that within the breeds and crosses this was not an important association.

Summary

A significant differene was found between sows of the different breeds and crosses in the amount of milk produced during a 6-week lactation period.

A peak in lactation was reached in the third week by the Duroc and Landrace x Poland sows, in the fourth week by the Poland sows and in the fifth week by the Landrace sows. Superior performance, as measured by litter size and weight, was shown by the Landrace sows which reached a peak in milk production late in the lactation period.

The milk yield of the sow was significantly correlated with the size of the litter suckled, the litter weight at weaning and the change in weight of the sows during lactation. It was not significantly correlated with the weight of the sows at the time of farrowing. A positive correlation was found between the amount of milk produced by the sow and the amount of creep feed consumed by her litter, pigs of sows producing the most milk consuming the most creep feed.

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EFFECTS OF TIME AND LEVEL OF SUPPLEMENTATION ON BEEF STEERS FED ALFALFA SOILAGE OR HAY

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EARLIER studies at this station have compared the production of nutrients and of beef from alfalfa harvested by various methods (Ittner *et al.*, 1954; Meyer *et al.*, 1956; Lofgreen *et al.*, 1956; Hull *et al.*, 1957). Although relatively good gains can be achieved on high quality alfalfa either as soilage or hay as the sole source of feed, it is well recognized that an additional source of energy is needed to produce a finished animal with a high dressing percentage and a high grading carcass in a reasonable feeding period. It was shown in an earlier study (Meyer *et al.*, 1953) that barley fed at the rate of 1 lb. per 100 lb. body weight to steers receiving alfalfa soilage brought about an increased daily gain of approximately 0.5 lb. Molasses alone was shown to be unsatisfactory as a supplement to alfalfa soilage. Other observations at this station and experiences in the field have shown a mixture of barley and molasses dried beet pulp (hereafter referred to merely as beet pulp) to be a satisfactory supplement to both alfalfa soilage and hay.

Steers fed alfalfa alone have consistently made good body weight gains, especially during the first half of a 130- to 179-day feeding period. The question arises as to the value of a concentrate supplement fed during the last half of the feeding period in contrast to supplementing continuously for the entire period. It also seemed important to determine at what level the supplement should be fed. The studies reported herein were designed to provide information on these two questions when barley and beet pulp were used as the supplement.

Experimental

Experiment 1. Thirty-six head of high quality yearling Hereford steers weighing approximately 665 lb. were randomly assigned to six groups in the 2 x 3 factorial design shown in table 1. The animals were fed in groups of three, the purpose being to obtain the beneficial effect of competition on feed consumption and at the same time sub-divide the feed intake for each group into two observations.

Animals were confined in pens designed especially for feeding in groups of three. The unit of feed intake for purposes of statistical analysis was the consumption of a pen of three animals. Feed was provided twice daily, all feed being weighed and sampled as fed. The hay fed was a

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composite of all hay harvested at approximately 10% bloom at the Imperial Valley Field Station the summer immediately preceding the study and was of good quality. The soilage was harvested at approximately 10% bloom. Sufficient barley and beet pulp were obtained prior to the trial to last throughout to insure a uniform composition of the feed. The steers were allowed hay and soilage *ad libitum*, and records were kept of feed refused. Barley and beet pulp were fed in ratio of 3 to 1 and all supplemented lots were allowed all the supplement they would eat twice daily. All lots were allowed a small amount of oat hay (averaging approximately 1.8 lb. per head per day) to assist in preventing bloat. Individual body weight measurements were taken initially and every 28 days after a 12-hour shrink. The initial weight was taken after the animals had been accustomed to their respective dietary treatments for one week. At the

TABLE 1. DESIGN OF EXPERIMENT 1

Roughage	Supplement treatment		
	None	Second 84-day period	Continuous for 168 days
	No. of steers		
Alfalfa soilage	6	6	6
Alfalfa hay	6	6[a]	6[a]

[a] One steer in each of these lots was lost to causes not associated with the treatment.

conclusion of the 168-day feeding period, all animals were slaughtered and data obtained on carcass yield and grade.

Experiment 2. Forty-eight short yearling Hereford steers of high quality weighing approximately 540 lb. were randomly divided into six lots each of eight head. Five of the lots were allowed alfalfa soilage *ad libitum* with various levels of barley and beet pulp supplement. One lot received no supplement while a second received all the supplement they would eat twice daily. The remaining three lots being fed soilage received the supplement at the rate of 75, 50 and 25% of the amount being consumed by the full-fed lot. The sixth lot was allowed alfalfa hay *ad libitum* plus the supplement full-fed. The feeding, weighing, and sampling procedures were similar to those described for experiment 1 except that the feeding was done by lot rather than in pens of three. The alfalfa soilage and hay were again harvested from the Imperial Valley Field Station fields at approximately 10% bloom, and sufficient barley and beet pulp were purchased at one time to last throughout the study. All lots were fed for 167 days and were slaughtered on the same day. Data were obtained on carcass yield and Federal grade.

During the progress of the study, sufficient samples were taken of all feeds to conduct digestion trials. At the conclusion of the feeding trial,

the feed samples thus saved were combined in the proper proportions to represent the six dietary treatments and were fed to six wether lambs in a 6 × 6 Latin square design. Total digestible nutrients (TDN) were determined from digestible organic matter by the method developed at this station (Lofgreen, 1953). Preliminary periods and collection periods were of 7 days' duration each during which all lambs were maintained on a constant intake. The data obtained from these trials were used to determine the TDN intake of the animals in experiments 1 and 2.

Results and Discussion

Experiment 1. Statistical analysis revealed no significant difference between the animals fed soilage or hay in their response to the supplements.

TABLE 2. RESPONSE OF STEERS SUPPLEMENTED AT VARIOUS TIMES IN EXPERIMENT 1

Supplemental treatment	Feeding period	No. of steers	Initial weight	Daily gain	Daily air-dry feed intake		Daily TDN intake
					Roughage	Concentrate	
			lb.	lb.	lb.	lb.	lb.
None	1st 84 days		670	1.89	16.7	0	8.9
	2nd 84 days	12	829	1.67	19.2	0	10.2
	Entire period		670	1.78	18.0	0	9.6
Supplemented second 84 days	1st 84 days		666	2.02	16.2	0	8.6
	2nd 84 days	11	836	2.39	14.1	7.6	13.4
	Entire period		670	2.21*	15.2*	3.8	11.0*
Supplemented for 168 days	1st 84 days		660	2.50	12.2	5.7	10.9
	2nd 84 days	11	870	1.86	11.8	7.5	12.1
	Entire period		660	2.18*	12.0*	6.6	11.5*

* A statistically highly significant difference was observed compared to the unsupplemented lot.

The daily gains and the roughage consumption on hay or soilage were not significantly different. The supplemented steers on hay, however, consumed an average of 2.2 lb. per head per day more concentrate than those on soilage. Since the gains were not different, the hay, therefore, was of lower nutritive value than the soilage. This is in agreement with the results reported earlier (Meyer *et al.*, 1956) showing alfalfa hay harvested from the same crop as soilage promoted lower gains in body weight. Because of the similarity in the response to supplement, the data from lots fed hay have been combined with those fed soilage and are presented in table 2.

The concentrate supplementation during the second half of the feeding period resulted in a highly significant increase in the daily TDN consumption of 3.2 lb. per day, although there was a highly significant drop in roughage consumption. The over-all daily gain was increased by 0.72 lb. It is interesting that the daily gain of the unsupplemented lot dropped

0.22 lb. during the second half of the feeding period, while providing 7.6 lb. of concentrate daily prevented this loss and increased the rate of gain 0.37 lb. above the gain of the first half. Supplementation throughout the 168-day period resulted in a further decrease in roughage consumption with only a slight increase in TDN intake. The daily gain was not increased over the group receiving supplement only the last half of the period, although approximately 75% more supplement was used over the 168 days.

It appears from these data that supplementation throughout the feeding period is wasteful of concentrate since the extra supplement reduced roughage intake but did not increase weight gain. An inspection of the slaughter data in table 3, however, shows that those steers supplemented throughout

TABLE 3. SLAUGHTER DATA FROM ALL LOTS OF STEERS IN EXPERIMENT 1

Supplemental treatment	Dressing percent	Steers with carcass grades of—		
		Choice	Good	Standard or commercial
		%	%	%
None	56.7*	8	75	17
Supplemented second 84 days	58.9*	18	82	0
Supplemented for 168 days	60.8*	64	36	0

* Statistically significant difference (0.05).

the 168 days, although gaining no more, yielded a significantly higher percentage of dressed carcass and graded considerably higher. A higher energy ration, therefore, may produce fatter carcasses without increasing the rate of gain. This observation is of utmost importance since it emphasizes the fallacy of interpretation of the results of feeding tests solely on the basis of body weight gains. In this study, interpretations based on gains alone would lead to erroneous conclusions.

One must conclude from these data that the composition of the body weight gain of the continuously supplemented steers was different from that of those supplemented only during the last 84 days. The data of Garrett (1957) on the composition of the gain of beef steers gaining at different rates provides information which is of interest in connection with this study. From his data, it is possible to estimate the percentage fat in the bodies of steers grading Choice, Good, and Standard. It is also possible to estimate the energy retention of steers of different body fat content. From these two values, the energy content per pound of gain for steers of different grades can be estimated. For example, the mean fat percentage in the bodies of Choice, Good, and Standard steers was 23.8, 18.0 and 14.5%, respectively. The energy content per pound of gain of steers of various grades can be estimated from the regression of the energy per pound of gain on the final fat percentage in the whole steer body at

slaughter. This relationship for all of Garrett's steers gaining 1 lb. or more per day is described by the equation, Y=293 X—3748, where Y is the kilocalories of energy per pound of weight gain and X is the percent fat in the whole steer body at slaughter. Such calculations resulted in the following values: 3225, 1526 and 501 kcal. per pound of gain for cattle grading Choice, Good and Standard, respectively. Applying these values to the grade of the cattle in the three supplemental groups results in estimates of the daily energy gain of 2644, 4049 and 5722 kcal. for the unsupplemented, supplemented the last 84 days, and the continuously supplemented lots, respectively. Even though these values may not represent the exact energy gained, they can be considered as indicating the relative

TABLE 4. THE NET ENERGY VALUE OF THE RATIONS FED IN EXPERIMENT 1

Supplemental treatment	None	Supplemented second 84 days	Supplemented entire 168 days
Net energy for maintenance, kcal.	5362	5520	5481
Energy in body weight gain, kcal.	2649	4049	5722
Net energy, kcal.	8011	9569	11203
Daily air-dry feed intake, lb.	18.0	19.1	18.6
NE per 100 lb. feed, megacal.	44.5	50.1	60.2
Daily TDN intake, lb.	9.6	11.1	11.5
NE per lb. TDN, megacal.	0.83	0.86	0.97

comparison among the three lots. The lot receiving continuous supplementation thus gained approximately 40% more energy than the lot supplemented only the last 84 days, although the gain in body weight was the same for the two lots.

A consideration of all data prompts the conclusion that in order to produce a high-grading and high-yielding carcass, continuous supplementation was more satisfactory than no supplementation or supplementation only during the last half of the feeding period.

One can estimate the net energy (NE) of the rations used in this study by calculating the NE required for maintenance by the equation, $NE = 35\ W^{\frac{3}{4}}$ (Garrett, 1957) and adding to this the energy in the body weight gain as estimated above. Since the TDN intake has been determined, one can then determine the NE in a pound of TDN from the three treatments. Such a comparison is presented in table 4. The value of 44.5 megacal. per 100 lb. for the unsupplemented roughage can be compared to Morrison's (1956) estimated value of 43.5 megacal. for very leafy alfalfa hay. The high quality of this forage is supported by the mean daily gain of 1.78 lb. for animals receiving no supplement for 168 days and the 0.83 megacal. of NE per pound of TDN. By way of comparison, Moore *et al.* (1953) indicated that one pound of TDN in good hay was equivalent to 0.75 megacal. NE and one pound of TDN in corn was equivalent to one megacal.

NE. The data from the two supplemented groups again emphasizes the advantage of the continuously supplemented group.

Experiment 2. The results of experiment 2 are presented in table 5. Feeding a supplement above 3.5 lb. per head per day (50% of full feed) to animals on alfalfa soilage produced no significant increase in weight gain. Increasing the supplement to 5.1 and 6.2 lb. per day brought about an increased TDN consumption but no increase in gain. It is again interesting to note that the steers full-fed supplement on alfalfa hay ate more concentrate than those full-fed supplement on alfalfa soilage. The difference in gain between these two lots was not statistically significant.

TABLE 5. RESPONSE OF STEERS SUPPLEMENTED AT DIFFERENT LEVELS IN EXPERIMENT 2

Treatment	Alfalfa soilage plus supplement fed at following percentage of full feed					Alfalfa hay plus supplement full-fed
	0	25	50	75	100	
Initial weight, lb.	541	545	543	542	543	539
Daily gain, lb.	2.01	2.17	2.28	2.34	2.35	2.53
Daily air-dry feed consumed, lb.						
Roughage	18.3	17.1	14.6	14.0	12.5	11.7
Concentrate	0	1.8	3.5	5.1	6.2	8.5
Total	18.3	18.9	18.1	19.1	18.7	20.2
TDN intake, lb. per day	10.1	10.7	10.7	11.6	11.6	12.7
Dressing percent	58.5	57.7	58.3	59.7	59.8	60.4
Carcass grade, no. in grade						
Choice	0	0	1	4	3	4
Good	7	8	7	4	5	4
Standard or commercial	1	0	0	0	0	0

As in the case of experiment 1, if only the body weight gain and TDN consumption are considered, erroneous conclusions may be made. From these data alone it appears that there is no advantage of feeding more than 50% of full feed or 3.5 lb. per head per day (approximately 0.5 lb. per 100 lb. body weight). Again, however, if the yield and grade data are considered, the conclusion is altered. Although increasing the supplement above 3.5 lb. did not significantly stimulate daily gains, it brought about a significant increase in the dressing percent and in the carcass grade. There was no significant advantage of supplementing above the 75% of full-feed level. Increasing the supplement to the full-fed level caused a sufficient reduction in roughage consumption to offset completely the increased concentrate intake. The daily gain, TDN intake, yield and grade remained unchanged. This study indicates, therefore, that a continuous supplement of concentrate to alfalfa soilage at a level of approximately 0.5 lb. per

100 lb. body weight results in maximum stimulation of gain, but increasing the level to 0.7 lb. significantly increases the yield and grade without stimulating gain. There appeared to be no advantage of increasing the supplement to the limit of the animals' appetite, although this amounted to only approximately 0.84 lb. per 100 lb. body weight in this experiment.

The NE of the rations has been estimated as in the case of experiment 1, and these data are presented in table 6. These estimates confirm the earlier conclusion that the 75% of full feed produced maximum utilization of the supplement. This is shown by the maximum value of 0.91 megacal. of NE per pound of TDN achieved at this level. The value of 0.87 for hay and

TABLE 6. THE NET ENERGY VALUE OF THE RATIONS FED IN EXPERIMENT 2

Treatment	Soilage plus following percentage of full feed					Hay plus full feed
	0	25	50	75	100	
Net energy for maintenance, kcal.	4809	4897	4935	4956	4963	5023
Energy in body weight gain, kcal.	2810	3311	3963	5560	5584	6011
Net energy, kcal.	7619	8208	8898	10516	10547	11034
Daily air-dry feed intake, lb.	18.3	18.9	18.1	19.1	18.7	20.2
NE per 100 lb. feed, megacal.	41.6	43.4	49.2	55.1	56.4	54.6
Daily TDN intake, lb.	10.1	10.7	10.7	11.6	11.6	12.7
NE per lb. TDN, megacal.	0.75	0.77	0.83	0.91	0.91	0.87

a full feed of concentrate again confirms the fact that the nutritive value of alfalfa fed as hay is usually somewhat lower than the same crop fed as soilage. The values are in good agreement with those suggested by Moore *et al.* (1953) as the NE value of good hay and a high quality concentrate.

Summary

A study on the time of concentrate supplementation to rations made up of maximum amounts of alfalfa hay or alfalfa soilage indicated that a continuous supplement of barley and beet pulp was superior to a supplement fed only the second half of the feeding period. Although daily gains were not stimulated, the dressing percent and carcass grades were improved. Evidence is presented showing the gains made by the steers being continuously supplemented contained more energy than the gains of the other groups.

A second study indicated that the level of continuous barley and beet pulp supplementation to alfalfa soilage should amount to approximately 0.7 lb. per 100 lb. body weight. This level did not significantly stimulate daily gains above 0.5 lb. per 100 lb. body weight but increased the dressing percent and carcass grade. Evidence is presented showing that this level increased the energy content of the gain, although not significantly in-

creasing the gain. The data presented emphasize the danger of misinterpretation of the results of feeding trials based solely on weight gain and feed consumption.

The estimated NE in megacal. per pound of TDN varied from an average of 0.79 for roughage alone to 0.93 for rations averaging 68% roughage and 32% barley and beet pulp.

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BLACK-EYED PEAS AS A SWINE FEED

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CULL black-eyed cowpeas, or black-eyed peas (*Vigna sinensis*), are often fed by California hog growers. Little experimental feeding information is available on this variety of cowpea, even though Morrison (1956) mentions that cowpeas are a suitable swine feed. It was reported many years ago that a mixture of corn and cowpeas or cowpeas alone produced more gain than corn alone (Duggar, 1897; Gray *et al.*, 1908). The rations in those studies were not adequate, however, as judged by current feeding standards (Morrison, 1956). Work on cull peas has been summarized by Cunha *et al.* (1948). Peas, being of a different genus than cowpeas, probably have a different feeding value and are treated separately as a feed by Morrison (1956).

Recently, a hog grower in Northern California suffered a high mortality among a group of hogs fed high, but varying, levels of black-eyed peas. Poisoning by the black-eyed peas was suggested even though a search of available literature failed to produce any evidence in this respect.

Experimental

Cleaned cull black-eyed peas [3] of the following composition were used in this experiment: dry matter, 91.5%; crude protein, 23.2% ether extract, 1.0%; crude fiber, 2.6%; and ash, 3.8% (A.O.A.C., 1955). They were fed in the rations given in table 1. Ration 2 differed from ration 1 by the substitution of 20% black-eyed peas for an equal amount of barley. This substitution caused an increase in the crude protein content of the ration. In ration 3, black-eyed peas were substituted for barley and all of the cottonseed and soybean meals, giving the ration a crude protein content about equal to that of ration 1.

Twenty-four purebred Duroc Barrows weighing about 80 lb. were sorted into four lots and assigned to rations at random. They were fed in concrete pens with self-feeders for an experimental period of 70 days. At the conclusion of this period two hogs were picked at random from each lot for slaughter. The four remaining hogs being fed ration 4 (50% black-eyed

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TABLE 1. PERCENTAGE COMPOSITION OF RATIONS FED TO PIGS[a]

Ration number	1	2	3	4
Ground barley	80.5	60.5	68.5	38.5
Ground black-eyed cowpeas	....	20	20	50
Dehydrated alfalfa meal	5	5	5	5
Soybean oil meal	4	4	....	....
Cottonseed meal	4	4	....	....
Meat and bone scraps (45% protein)	6	6	6	6
Salt	0.5	0.5	0.5	0.5

[a] Plus 0.45 lb. zinc sulphate per ton.

peas) were switched to a ration of black-eyed peas alone for an additional 28 days and then slaughtered.

At slaughter the hogs were studied macroscopically, and kidney samples were taken for histological study.

Results and Discussion

Results of the 70-day feeding trial are given in table 2. They clearly indicate that the substitution of black-eyed peas for barley, or for barley and the oil meals, causes a reduction in weight gain. Less feed was apparently consumed when black-eyed peas were included in the ration. Statistical analysis of feed data could not be carried out as the animals were group-fed. Feed utilization appeared lowest on the ration containing 50% black-eyed peas.

Rations containing black-eyed peas did not appear as palatable as the control ration, and much more feed was wasted. The 50% black-eyed pea group (ration 4) had the greatest wastage.

During the 28-day period on a ration of straight black-eyed peas, the group of four hogs gained 0.59 lb. per pig per day and consumed only

TABLE 2. GAIN AND FEED CONSUMPTION OF PIGS[a] FED BLACK-EYED PEAS

	1	2	3	4
		Black-eyed peas		
Ration number and description	Control	20%	20%	50%
Initial weight, lb.	79.0	81.3	79.7	80.0
Av. total gain, lb.[b]	110.3	91.0	87.0	68.3
Av. daily gain, lb. per pig	1.58	1.30	1.24	0.98
Av. daily feed consumption, lb.	5.76	4.58	4.53	4.09
Feed per lb. of gain, lb.	3.65	3.52	3.65	4.17

[a] Six pigs per lot for 70 days.

[b] Analysis of variance yielded a mean square which is statistically highly significant ($P<0.01$). The Duncan (1955) multiple range test showed that gains of pigs on both rations 1 and 4 differed from all other lots at the 1% level. The difference in gains between pigs on rations 2 and 3 lacked statistical significance.

3.43 lb. of black-eyed peas (or ration) per pig per day. Feed consumption was very low initially, but increased to almost 5 lb. daily at the conclusion of the 28 days.

Macroscopic examination at slaughter and histological study of the kidneys showed no apparent differences between hogs fed the different rations.

Summary

Twenty-four growing hogs with an initial weight of about 80 lb. were fed a control ration and rations containing 20% and 50% ground black-eyed cowpeas (*Vigna sinensis*) for an experimental period of 70 days. As the percentage of black-eyed peas increased, gain in weight decreased. The pigs on the ration containing 50% black-eyed peas gained about 38% less weight than the controls (1% level of statistical significance). Feed consumption and utilization were apparently reduced by the addition of black-eyed peas. There was no evidence of toxicity.

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SPECIFIC GRAVITY AS AN OBJECTIVE MEASURE OF BEEF EATING QUALITY [1]

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TENDERNESS is probably the most "looked for" trait in meat. Ultimate consumer acceptability and satisfaction for a particular cut of meat can be largely attributed to this trait. Meat tenderness, or the lack of tenderness, has been attributed to various factors. Lehmann (1907), Mitchell *et al.* (1928), Mackintosh, Hall and Vail (1936), and Cover (1937) have reported that tenderness is inversely related to the amount of connective tissue present in meat. The muscle fiber, itself, has also been studied (Moran and Smith, 1929; Hiner *et al.*, 1953; Wang *et al.*, 1956). The influence of the fat content of meat (marbling) upon its ultimate tenderness is obscured by contradictory reports. Hankins and Ellis (1939) found insignificant relationships between tenderness and certain fat indexes. Cover, Butler and Cartwright (1956) reported that degree of finish was the more indicative of juiciness in broiled steaks, whereas, with either broiled or braised bottom round steaks, tenderness showed a higher relationship to finish. Other factors reported to affect tenderness include age, breed, sex, and length of ripening.

Specific gravity has been used extensively by various workers (Brown, Hillier and Whatley, 1951; Whiteman, Whatley and Hillier, 1953; Breidenstein *et al.*, 1955; Pearson *et al.*, 1956; Price *et al.*, 1957; Orme *et al.*, 1958; Backus, 1958, Saffle and Bratzler, 1959) as an objective measure of fat in pork cuts, carcasses, and beef cuts.

Various objective and subjective measures of tenderness have been devised, to which certain limitations have been affixed. An objective measure of tenderness applicable to the carcass or to a portion of raw meat from the carcass would be extremely advantageous. Since specific gravity can be used with the carcass or a part thereof, this study was undertaken to investigate the relationship of specific gravity to meat tenderness.

Experimental Methods

One hundred beef ribs of comparable age, with the exception of the commercial cow ribs, equally divided among the Prime, Choice, Good, Standard, and Commercial (cow) grades were purchased from a local packer in two groups of fifty. The average weights by grade for these ribs

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were 30.96, 26.58, 24.03, 23.90 and 24.40 lb. for Prime through Commercial grades, respectively. Each rib was aged 14 days in a thermostatically controlled cooler (36° F.±2.0). Loin eye area for each rib was obtained by the use of a compensating planimeter and a tracing taken of the cut surface of the 12th rib. Fat covering was measured as outlined by Naumann (1951), with one slight modification in that the measurement taken nearest the proximal end included only the distance from the exterior edge of fat to the edge of the *Spinalis dorsi* muscle, rather than the exterior edge of fat to the edge of the *Longissimus dorsi* muscle. A subjective score, based on the standards given in U.S.D.A. Publication 99, was given each rib by three judges.

Each rib was cut following the procedure stated by Hankins and Howe (1946). A detailed separation of lean, fat, and bone of each 9-10-11 rib section was made and all weights were recorded to the nearest 0.1 lb. Specific gravity, using the hydrostatic weighing technique, was determined on the *Longissimus dorsi* muscle of the 9-10-11 rib section which had previously been uniformly cleaned of intermuscular fat. Weights in both air and water were taken to the nearest 0.1 lb. with the temperature of the water held constant throughout. The portion of the eye muscle was then blotted dry, chopped until homogenous (approximately 5 minutes) in a Model T-125 Hobart food chopper, and then wrapped and frozen for subsequent chemical analyses. Water and protein determinations were made by the procedure of Benne, Van Hall and Pearson (1956), whereas ether extract was obtained by extracting a moisture-free sample for 4 hours.

Cooking and organoleptic tests, using a frozen boneless roast from the 6-7-8 rib sections, were conducted by the Food Research section of the College of Home Economics. The frozen roasts were weighed (nearest 0.1 gm.), placed fat side up in a previously heated (275° F.) Despatch oven, and cooked at this temperature until sufficiently thawed to allow the insertion of a meat thermometer into the center of each roast. At this point the temperature of the oven was increased to 300° F. and the roasts were cooked until an internal temperature of 154.4° F. was reached. The cooked roasts were then removed and allowed to stand at room temperature 10 minutes, so as to reach a maximum internal temperature before reweighing and cutting. Evaporation, drip, and total cooking losses were obtained for each roast.

A trained taste panel consisting of six members was used to evaluate each roast for tenderness, juiciness, and flavor. Ratings were made using a numerical scale of 1 through 9; number 9 represented the optimum for each trait scored. Mechanical tenderness values were also obtained on all ribs with the Warner-Bratzler shear.

Analysis of variance and simple correlation coefficients were calculated on a within group and grade basis as outlined by Snedecor (1956).

Results and Discussion

The averages by grade for certain objective, subjective, and chemical evaluations are shown in table 1. For ribs in the first four grades (Prime, Choice, Good, and Standard), definite linear trends with grade are evident for all traits listed, but the Commercial grade fails to be consistent with these trends. This failure of values for the Commercial grade to fit patterns set by the other grades is to be expected since this grade has finish

TABLE 1. AVERAGE VALUES BY GRADES, OF CERTAIN SUBJECTIVE, OBJECTIVE, AND CHEMICAL EVALUATIONS OF BEEF RIBS

Grades[a]	Prime	Choice	Good	Standard	Commercial	σx[b]
Loin eye area, sq. in.	10.06	9.62	8.91	9.52	9.06	0.28
Fat thickness at 12th rib, cm.	2.49	2.13	1.68	1.27	2.62	0.11
Subjective marbling score[c]	1.75	3.45	5.80	7.10	3.40	0.23
Specific gravity of 9-10-11 rib section	1.056	1.060	1.064	1.067	1.057	0.94^{-3}
Percent separable lean 9-10-11 rib	40.75	43.39	46.70	51.19	41.33	0.89
Percent separable fat 9-10-11 rib	46.76	42.95	37.01	30.67	43.66	1.03
Percent separable bone 9-10-11 rib	12.11	13.65	16.09	18.09	15.46	0.38
Percent moisture in 9-10-11 rib[d]	67.51	70.31	72.00	72.97	68.89	0.42
Percent fat in 9-10-11rib[d]	11.00	7.53	5.96	4.18	8.39	0.52
Percent protein in 9-10-11 rib[d]	20.26	20.55	21.05	21.63	21.11	0.21

[a] Average difference among grades significant at P=.01 for all traits.
[b] Calculated from the pooled sum of squares within grade, 20 observations per grade.
[c] Numerical values were assigned to subjective marbling as follows: 1—very abundant, 2—abundant, 3—moderately abundant, 4—slightly abundant, 5—moderate, 6—modest, 7—small amount, 8—slight amount, 9—traces, 10—practically devoid, 11—none.
[d] Excludes bone.

comparable to the Prime and Choice grades but comes from mature hard-boned cattle. For this reason, analysis of variance and correlation coefficients were calculated with and without the Commercial ribs. For the first four grades, fat covering and intramuscular fat decreased as the grade moved from Prime to Standard, with an average difference between successive grades amounting to 0.41 cm. and 1.78 points (marbling score), respectively. The Commercial ribs had the thickest fat covering of all grades and were about equal to the choice ribs in subjective marbling score.

Specific gravity values for the excised *Longissimus dorsi* muscle from the 9-10-11 rib section for grades Prime through Commercial were 1.056, 1.060, 1.064, 1.067, and 1.057, respectively. With the exception of the Commercial ribs, which had an average value almost equal to the Prime

ribs, specific gravity was inversely related to the four higher grades of beef. Since specific gravity has been reported by Orme *et al.* (1958) to be a reliable index of the quantity of intramuscular fat, such a relationship would be expected. A significant relationship (P=.01) was found between grade and the average specific gravity for a particular grade. However some overlapping of specific gravity on grade occurred for the specific gravity of individual ribs.

The percent of either separable lean or bone in the 9-10-11 rib sections and the percent of chemically determined moisture or protein from the loin eye of the 9-10-11 rib section all showed an inverse relationship to grade for the four top grades of beef, when grade averages for the respective items were compared. On the other hand, the commercial ribs were similar to the Prime and Choice for percent lean, to the Choice and Good for percent bone, and to the Good for percent protein (table 1). The percent of separable fat in the 9-10-11 rib sections and percent of chemically determined fat in the loin eyes of the 9-10-11 rib sections were linear and directly related to the four top grades of beef. Thus, the Prime ribs contained the highest percent of separable and chemical fat and the smallest percent of lean, bone, moisture and protein; conversely, the Standard ribs had the highest percent of lean, bone, moisture, and protein and the smallest percent of either separable or chemical fat.

Analysis of variance showed highly significant (P=.01) differences among grades (Commercial ribs included or excluded) for all items listed in table 1.

Average grade palatability scores, shear values, and cooking losses obtained from the 6-7-8 rib roasts are listed in table 2. Flavor of lean, tenderness, juiciness and total palatability scores decreased progressively from Prime through the Commercial grades. Shear values, with the exception of the Good ribs which sheared on the average 1.03 lb. less than the Choice graded ribs, showed the same linear trend to grade. Prime ribs had the lowest shear values (indicating more tender meat) whereas the Commercial ribs obtained from mature hard-boned cattle, had the highest shear values, indicative of less tender meat.

Cooking losses (table 2) followed the same pattern to grade as was found with the percent of either fat or moisture (table 1). The Standard ribs were leanest and highest in moisture content and showed the greatest (P=.01) evaporation loss and the lowest (P=.01) drip loss. On the other hand, excluding the Commercial ribs, the highest drip loss and lowest evaporation loss were incurred with the Prime ribs, which had the largest average amount of intramuscular fat (separable fat) and intramuscular fat (marbling). Therefore, high loss in drip or excessive evaporation losses were directly related to high fat content or high moisture content in meat, respectively. The Commercial ribs had the highest (P=.01) average drip loss which probably was due largely to the thick covering of external fat. Total cooking loss (drip + evaporation loss) was inversely related to grade

TABLE 2. AVERAGE VALUES, BY GRADES, OF PALATABILITY SCORES, SHEAR VALUES, AND COOKING LOSSES OF 6-7-8 RIB ROASTS

Grades[a]	Prime	Choice	Good	Standard	Commercial	$\sigma\bar{x}$[b]
Flavor of lean[c]	7.87	7.68	7.39	7.10	6.97	0.09
Tenderness scores[c]	8.12	7.79	7.63	7.15	6.49	0.14
Juiciness scores[c]	7.85	7.55	7.29	7.18	7.09	0.13
Total palatability[d]	23.83	23.01	22.30	21.43	20.54	0.30
Shear values, lb.	13.75	15.73	14.70	17.39	18.10	0.77
Drip loss, %	6.46	5.80	5.10	4.10	6.86	0.35
Evaporation loss, %	15.58	16.83	17.74	19.15	17.29	0.43
Total cooking loss, %	22.04	22.62	22.83	23.24	24.14	0.53

[a] Average differences among grades significant at P=.01.
[b] Calculated from the pooled sum of squares within grade with 20 observations per grade.
[c] Scores for palatability were based upon the following: 9—excellent, 8—very good, 7—good, 6—fair plus, 5—fair, 4—fair minus, 3—poor, 2—very poor, 1—extremely poor.
[d] Sum of flavor of lean, tenderness, and juiciness scores.

since the Commercial ribs were associated with the largest total loss and progressively smaller losses were incurred up through Prime which had the least cooking loss.

Analysis of variance showed highly significant differences between grade (P=.01) for the various items listed in table 2, but failed to reveal any significant differences for ribs of the same grade.

Table 3 lists the simple correlation coefficients of specific gravity with

TABLE 3. SIMPLE CORRELATION COEFFICIENTS OF SPECIFIC GRAVITY WITH SELECTED PHYSICAL AND CHEMICAL FACTORS

	r Specific gravity	
Factor	Includes commercial[a]	Excludes commercial[b]
Fat thickness of 12th rib	—.57	—.52
Subjective marbling	0.72	0.78
Separable lean 9-10-11 rib	0.67	0.56
Separable fat 9-10-11 rib	—.40	—.35
Chemical fat	—.77	—.81
Tenderness score	—.04	—.31
Juiciness score	—.35	—.41
Flavor of lean score	—.28	—.45
Total palatability score	—.23	—.45
Sheer values	0.06	0.16
Drip losses	—.60	—.53
Evaporation losses	0.41	0.45
Total cooking losses	—.11	0.12
Grade	0.17	0.72

[a] 0.195 required for significance at P=.05.
0.254 required for significance at P=.01.
[b] 0.217 required for significance at P=.05.
0.283 required for significance at P=.01.

various physical and chemical factors, when including and excluding the Commercial ribs. Deleting the Commercial ribs seemed advisable so as to present a more complete picture of the whole perspective since (1) Commercial ribs are not used to the same extent in retail trade channels as are ribs from the four higher grades; (2) decreased tenderness; and (3) the relative high fat content of the Commercial ribs which measurably affects specific gravity. With the exception of fat thickness, separable lean, separable fat, drip loss, and total cooking loss, all relationships between specific gravity and the various items listed in table 3 were improved somewhat by the elimination of the Commercial ribs. Specific gravity was found to be highly related to the various physical and chemical measurements which are principally measuring the amount of fat. Such factors as fat thickness —.57, separable fat —.40, chemical fat —.77, and drip loss —.60 showed highly significant inverse relationships to specific gravity; whereas subjective marbling .72, as designated in this study, separable lean .67, and evaporation loss .41 (which showed an inverse relationship to fat content in meat) showed a direct and highly significant relationship to specific gravity. With the elimination of the Commercial ribs, specific gravity was found to be highly related to grade ($r=.72$).

The validity of using specific gravity as an objective measure of beef eating quality is somewhat questionable from the results of these data and those of Orme (1958) and Saffle and Bratzler (1959). Although the relationships between specific gravity and palatability scores (tenderness, juiciness, flavor, and total palatability) were highly significant, when discarding the Commercial ribs, only 10 to 20% of the variation in beef eating quality was explained by specific gravity. Tenderness values obtained by use of the Warner-Bratzler Shear were not significantly related to specific gravity. Specific gravity was found to be more highly related to such factors as juiciness and flavor than to meat tenderness.

Summary and Conclusions

Physical and chemical data were collected on 100 beef ribs, equally divided among the U.S.D.A. grades of Prime, Choice, Good, Standard, and Commercial. Exclusive of the Commercial ribs, as carcass grade decreased (Prime to Standard) there was a corresponding decrease in fat covering, separable fat, and chemical fat; whereas with an increase in grade (Standard to Prime) there was a corresponding increase in marbling, while specific gravity, percent separable lean and bone, and chemically determined moisture and protein content decreased. The Commercial ribs fell between the Prime and Good ribs for these various items.

Palatability scores were highest for the Prime ribs and decreased by grade through the Commercial ribs. Prime ribs also required less shear force and the Commercial ribs the most force in order to shear a standard sized

meat core. Drip and evaporation losses seemed to be proportional to the amount of finish.

The validity of using specific gravity as an objective measure of beef eating quality is questionable. Although highly significant correlation coefficients of —.45, —.45, —.41, and —.31 were obtained between specific gravity and total palatability, flavor of lean, juiciness, and tenderness scores, respectively, only 10–20% of the variation in beef eating quality was explained by specific gravity. On the other hand, specific gravity was found to be highly related to certain physical and chemical measures of fat. Correlation coefficients of —.57, +.72, —.77, and —.60 were obtained with fat thickness, subjective marbling, chemical fat, and drip loss, respectively.

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EFFECTS OF INJECTED OVARIAN HORMONES ON THE CORPUS LUTEUM OF THE ESTRUAL CYCLE IN CATTLE [1]

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THE effects of exogenous progesterone on the corpus luteum are quite variable. No gross or microscopic effects were apparent in the pregnant rat (Sammelwitz *et al.*, 1956; Aldred *et al.*, 1959) or rabbit (Ulberg, 1952). Selye (1939) reported no effect of progesterone on corpora lutea of late pregnancy in mice, but Burdick (1942) found that treatment begun one or two days post-mating caused luteal regression.

Whether or not progesterone is detrimental to corpora lutea, and the extent to which the corpora lutea are damaged, appears to depend upon the time of injection in gilts (Sammelwitz and Nalbandov, 1958) and ewes (Zimbelman *et al.*, 1959). Spies *et al.* (1958) found that progesterone treatment from the 10th to the 25th day after mating caused regression of corpora lutea in hysterectomized as well as in pregnant gilts, indicating that progesterone acts independently of the uterus.

Estrogen treatment has a beneficial effect on corpora lutea in rats (Hohlweg, 1934; Desclin, 1935; Selye *et al.*, 1935; Wolfe, 1935; Merckel and Nelson, 1940) and rabbits (Allen and Heckel, 1936; Heckel and Allen, 1939). Kidder *et al.* (1955) found that stilbestrol caused luteinization of follicles when injected on day-11 of the estrual cycle of gilts. Hammond and Day (1944) observed that corpora lutea persisted for prolonged periods in heifers implanted with stilbestrol, while Greenstein *et al.* (1958) reported that estradiol administered from day-2 through day-12 of the estrual cycle caused early regression of corpora lutea.

The purpose of this study was to determine the effects of injected progesterone and estrogen on the progesterone content, proportion of functional luteal cells, and weight of corpora lutea in open heifers.

Materials and Methods

The animals selected for these studies were observed through at least one estrual cycle and only those were used whose cycles were in the range of 17–25 days. The experiments were carried out so that each animal served as her own control. For this purpose, a "control" corpus luteum was removed via supra-vaginal incision on day-14 of an untreated estrual

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cycle. An interval of at least one ovarian cycle elapsed between the time that the control corpus was removed and the experimental treatment was begun. Three groups of 10 animals each were used in this investigation. One group (composed of one virgin heifer, one multiparous, and eight uniparous cows) was used to study the effects of progesterone injected on day-1 of the estrual cycle. Another group (all virgin heifers) was used in a study of effects of progesterone injected 5 days after estrus, and still another group of virgin heifers was used to determine the effects of estrogen treatment from day-1 through day-13 of the estrual cycle. Progesterone-treated animals were given a single subcutaneous injection of one mg. of progesterone in starch suspension per lb. body weight on the appropriate day of the treated estrual cycle. Heifers on estrogen treatment received 250 mcg. of estradiol-17β in corn oil per day subcutaneously on day-1 through day-13 of the treated estrual cycle. Corpora lutea were removed either at slaughter or by supra-vaginal incision on day-14 of the cycle.

Corpora lutea were weighed fresh and a small piece removed and fixed in Bouin's solution for histological study. The remainder of the gland was stored frozen in 95% ethanol and assayed chemically for progesterone at a later time. Sections of corpora lutea were stained with hematoxylin and eosin and characterized according to the percentage of type I and II luteal cells (Foley and Greenstein, 1958), which were the types presumed to be "functional". These percentages were transformed to angles for statistical analysis. Chemical assays for progesterone were usually done in duplicate by a modification of the method of Loy *et al.* (1957). The modification consisted of substituting for the hot 95% ethanol extraction, a similar extraction carried out at room temperature on a rotary shaker, and altering the proportions of chloroform used to develop and elute the column from 5% to 10% and from 20% to 25%.

In earlier work, extracts of swine corpora lutea were found to contain only progesterone (Loy *et al.*, 1957). However, Gorski *et al.* (1957) reported finding Δ^4-pregnene-20β-ol-3-one in extracts of bovine ovaries, and Hayano *et al.* (1954) reported this compound to be produced when progesterone was incubated with bovine corpus luteum tissue. It seemed advisable to examine extracts obtained in this study for the presence of such a substance. Twelve such extracts were chromatographed on paper in either a methylcyclohexane-propylene glycol or 80% methanol-Skellysolve B system. A contaminating steroid, thought to be Δ^4-pregnene-20β-ol-3-one on the basis of chromatographic behavior was found, but the mean level was less than 5% of the total steroid.

The finding of a steroid not progesterone in the purified extract of bovine corpora lutea, plus the fact that levels of steroid found in this study and others from this laboratory are somewhat higher than those found by Gorski *et al.* (1958), and several times higher than those found

by Melampy *et al.* (1959), made it appear desirable to establish more certainly that the major steroid component isolated was progesterone.

In comparisons of biological activity on rabbit uteri (Allen, 1930) with chemical assay, crude extracts in amounts equivalent to 560 and 765 mcg. of progesterone, as determined by chemical assay on comparable purified aliquots, gave reactions of +++ to ++++, and that equivalent to 1040 mcg. gave a ++++ reaction. Highly purified extracts eluted from paper chromatograms were tested biologically on three rabbits in amounts chemically estimated, directly from these extracts, to be equivalent to 500, 1000, and 1000 mcg. of progesterone. Responses to these extracts were ++ to +++, +++ to ++++, and ++++, respectively. Thus tests of biological activity agree well with chemical assays.

Steroid purified by countercurrent distribution after paper chromatography was crystallized from aqueous methanol. The spectrum of its sulfuric acid chromogen between 220 and 500 mμ exhibited a single absorption peak at 293 mμ which is the approximate wave length at which progesterone shows a similar maximum (Bernstein and Lenhard, 1953). The infrared spectrum[3] of the crystallized material showed the same absorption bands as the reference spectrum of β-progesterone and that published for progesterone (Dobriner *et al.*, 1953) in the spectral range of from approximately 700 to 1850 cm^{-1}. These results indicate that the compound which was isolated as the major steroid component is progesterone. Since the substance present as contaminant is assumed to be a naturally occurring progestogen (Zander *et al.*, 1958), the values used for statistical comparisons are those for progesterone and this substance combined.

Comparisons between treated and control values were made by the Student t-test or by the H-test of Kruskal and Wallis (1952). Correlations were calculated within each control and treated group. These were not heterogeneous for the three control groups, so sums of squares and cross products were pooled for calculation of correlations within the control groups.

Results

Progesterone injected on the day after estrus exerted a detrimental effect on corpora lutea as indicated by significant differences between treated and control for all three characteristics studied (table 1). The individual response of corpus luteum weight and proportion of functional luteal cells to treatment on day-1 was quite variable as shown by significantly increased variances. This tended to be true for progestogen concentration also, but the increase in variance was not significant.

Treatment with progesterone 5 days after estrus reduced progestogen concentration and percentage of functional cells significantly. It had no

[3] Infrared analysis was done by Dr. Alan F. Krivis of the Upjohn Company, Kalamazoo, Michigan.

TABLE 1. MEANS AND VARIANCES OF CHARACTERISTICS OF CORPORA LUTEA FROM OVARIAN HORMONE-TREATED HEIFERS AND OF CONTROL CORPORA LUTEA

	Progesterone, day-1		Progesterone, day-5		Estrogen, days 1–13	
Treatment group	Control	Treated	Control	Treated	Control	Treated
Corpus luteum						
Av. wt., gm.	5.17	3.63**	4.34	3.97	5.68	3.70**
Variance	1.22	5.67*	1.62	1.08	1.11	1.84
Progestogen conc.						
Av., mcg./gm.	49	29*	46	36*	37	32
Variance	232	405	97	137	170	578
Functional luteal cells						
Av., %	86	36**	85	65**	87	50**
Variance	23	786**	21	429**	23	313**

* Differs from control, $P<0.05$.
** Differs from control, $P<0.01$.

significant effect on the weight of corpora lutea, however, and even the downward trend was slight (table 1). Only the variance of percentage of functional cells was increased significantly by progesterone on day-5.

Administration of estradiol for 13 days beginning on the day after estrus exerted a marked depressing effect on the corpus luteum weight and percent of functional luteal cells, but progestogen concentration was not significantly changed by this treatment. Estrogen injection tended to increase the variance of all characteristics but the increase was significant only for the percentage of functional luteal cells (table 1).

The effect of progesterone treatment on day-1 is reflected also by the positive associations between weight, proportion of functional cells and progestogen concentration, which are significantly different from those in control corpora lutea (table 2). No significant changes in these associations

TABLE 2. CORRELATIONS AMONG CHARACTERISTICS OF CORPORA LUTEA FROM OVARIAN HORMONE-TREATED HEIFERS AND OF CONTROL CORPORA LUTEA

	Progesterone		Estrogen	
Treatment group	day-1	day-5	days 1–13	Control
Variables correlated				
Cells and functional weight	0.46[a]	0.27	0.52[a]	—.22
Conc. and weight	0.65*[a]	—.36	0.85**[b]	—.10
Conc. and functional cells	0.79**[b]	0.51[c]	0.55[c]	—.07

[a] Differs from control, $P<0.05$.
[b] Differs from control, $P<0.01$.
[c] Differs from control, $P<0.10$.
* Correlation significant, $P<0.05$.
** Correlation significant, $P<0.01$.

were effected by progesterone treatment on day-5. Associations between corpus luteum weight and percentage of functional cells and between weight and progestogen concentration were significantly changed by estrogen treatment, but that between functional cells and concentration was not (table 2).

Discussion

The results obtained by the injection of ovarian hormones appear to be explainable on the assumption that formation of the corpus luteum and maintenance of its function are dependent upon optimal ratios of estrogen and progesterone. The mechanisms by which imbalances of the ovarian hormones damage the corpus luteum are presumed to involve altered pituitary gonadotrophin secretion.

It has been shown that certain dosages of progesterone will prevent heat and ovulation and yet not interfere with follicular development (Dutt and Casida, 1948; O'Mary *et al.*, 1950; Ulberg *et al.*, 1951a, 1951b). Foote *et al.* (1958) found significantly higher levels of LH in the pituitary glands of gilts slaughtered immediately following a period of progesterone treatment than in those of similar gilts slaughtered 8 days later. It may thus be postulated that altering the ratio of ovarian hormones by injecting progesterone tends to depress LH activity by inhibiting its release from the pituitary; treatment following ovulation consequently would result in formation of corpora lutea which are poorly developed and maintained.

The regressive histological changes and lowered progestogen content with normal weight of corpora lutea from animals injected on day-5 suggest impaired maintenance. The relatively greater effects on day-1 are presumed to result both from faulty formation because of an early deficiency of LH, and from regressive changes due to lowered maintenance. Progesterone injection at comparable stages of the estrual cycle in swine (Sammelwitz and Nalbandov, 1958) failed to bring about reduction of corpus luteum weight; however, studies of other criteria of function of the corpora lutea were not reported.

Estrogen treatment causes production and/or release of LH, resulting in luteinization in rats (Hohlweg, 1934; Desclin, 1935; Wolfe, 1935; Merckel and Nelson, 1940) and swine (Kidder, 1955), although Kidder (1954) was unable to demonstrate this in the cow with the relatively large doses that were tested. It is postulated that stored LH is released first by estrogen treatment, following which that hormone is released as rapidly as it is produced (Fevold *et al.*, 1936; Hellbaum and Greep, 1946). Thus the luteinizing activity following the initial release may be quite low if treatment is continued. Corpus luteum formation may be limited by early depletion of the LH supply, and regressive histological changes may result from inadequate amounts of luteinizing hormone following formation.

An alternative explanation for the degenerative changes in corpora lutea resulting from estrogen treatment is that the LH being continually released

in small amounts following formation of corpora may become luteolytic (Greep, 1938). This view would not be consistent with the interpretation of results of progesterone treatment on day-5 as being due to the blocking of LH release and a consequent impairment of maintenance. The possibility exists that the effects of injected ovarian hormones on the corpus luteum are mediated by way of a luteotrophic substance other than LH, for example, lactogen, but the effectiveness of such a principle has not been demonstrated in tests on the bovine (Smith *et al.*, 1957).

Apparent differences between cattle and swine in the effects of injected ovarian hormones on the corpus luteum require further study. Some evidence suggests that the action of injected progesterone in preventing the release of LH from the pituitary glands of these species is similar (Ulberg *et al.*, 1951a, 1951b). The release of LH by estrogen has not been demonstrated in cattle. The effect in swine may not be uniform under all conditions (Kidder *et al.*, 1955; Foote *et al.*, 1958), and a similar situation may exist for the cow. Just what ratio of estrogen to progesterone could be expected to favor release of hypophyseal LH is not known. Further investigations should be made to ascertain whether or not estrogen causes release of LH in cattle, and, if so, under what conditions of dosage level and duration and at what stages of the estrual cycle or in the presence of what progesterone levels this might occur.

Summary

The effects of injected ovarian hormones on the corpus luteum of the estrual cycle were studied in heifers. One mg. of progesterone per lb. body weight in a single injection on day-1 of the cycle caused significant differences in corpus luteum weight, proportion of functional luteal cells, and progestogen concentration between treated and control corpora lutea on day-14. Positive associations between functional cells and weight, concentration and weight, and concentration and functional cells ($r=0.46$, 0.65, and 0.79, respectively) were significantly different from corresponding control correlations ($r=-.22$, $-.10$, and $-.07$, respectively). The same hormonal treatment on day-5 of the estrual cycle caused significant differences in proportion of functional cells and progestogen concentration, but not in corpus luteum weight. No significant change in associations of these characteristics was caused by this treatment. When heifers were given 250 mcg. of estradiol-17β per day from day-1 through day-13 of the estrual cycle, significant differences were found between treated and control corpora lutea for weight and proportion of functional luteal cells, but not for progestogen concentration. Associations between functional cells and weight, and concentration and weight were significantly altered from control values (r of 0.52 and 0.85 vs. $-.22$ and $-.10$, respectively), but the correlation between concentration and functional cells was not significantly affected by treatment (0.55 vs. $-.07$).

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A COMPARISON OF DIFFERENT METHODS OF IRON ADMINISTRATION ON RATE OF GAIN AND HEMOGLOBIN LEVEL OF THE BABY PIG [1]

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AN intramuscular injection of an iron-dextran complex in young pigs has recently been reported effective in preventing and treating anemia (Barber *et al.*, 1955, 1958; Brownlie, 1955; McDonald *et al.*, 1955). Since the initiation of the experiment reported herein, Rydberg *et al.* (1959a) and Ullrey *et al.* (1959) have reported that pigs injected with iron-dextran maintain higher hemoglobin levels than pigs given oral iron.

The experiment reported in this paper was conducted to determine the effect on growth and hemoglobin level of young pigs given (1) oral iron, injectable iron-dextran or injectable peptonized iron, (2) the effect of different levels of injectable iron-dextran, and (3) the effect of time of injection of iron-dextran.

Materials and Methods

Three hundred seventy-two purebred and cross-bred pigs completed this experiment. Data are not included for the pigs that died during the experiment. The purebred pigs included Duroc, Hampshire, Poland China, Spotted Poland China, and Yorkshire. All pigs were farrowed indoors in concrete floored pens. In trials I and II the pigs remained in these pens for the duration of the experiment; in trial III the pigs were transferred to rye pasture when approximately 3 weeks of age. All trials were conducted with spring farrowed pigs during the spring of 1959. Creep feed was not provided in an attempt to limit the dietary source of iron to the dam's milk.

Three treatments were used in each of the trials; they are described separately for each trial. The treatments were assigned in a random order, and pigs within litters were assigned to treatment without regard to weight or sex. Blood samples (marginal vein of the ear) were obtained for hemoglobin determination from 128 of the pigs in trials I and II. Hemoglobin was determined by use of the Bausch and Lomb Spectronic 20 colorimeter.

Trial I. One hundred sixty-nine pigs were allotted to the following treatments: (1) oral iron in the form of a pill containing 292 mg. of reduced

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iron, 16 mg. of copper sulfate and 2 mg. of cobalt sulfate, given shortly after birth and at 10 and 21 days of age; (2) a 2 ml. intramuscular injection of an iron-dextran complex providing 100 mg. of elemental iron as ferric hydroxide administered during the first day of life; (3) a 1 ml. intramuscular injection of a peptonized iron solution containing 250 mg. of peptonized iron administered during the first day of life and again at 21 days of age. All pigs were weighed at birth and 28 days of age. Hemoglobin and weight data were collected on 62 pigs at birth, 10, 21, and 28 days of age.

Trial II. All of the animals in this trial received iron-dextran intramuscularly as follows: (1) 2 ml. containing 150 mg. of elemental iron administered during the first day of life; (2) 2 mg. containing 100 mg. of elemental iron given at 7 days of age; (3) 2 ml. containing 100 mg. of elemental iron injected shortly after birth and an additional 2 ml. at 21 days of age. Sixty-six of the 106 pigs used in this trial were bled and weighed at birth, 1, 2, 7, 14, 21, and 28 days of age. The remaining pigs were weighed at birth and 28 days of age only.

Trial III. The treatments used were the same as in trial II except that approximately one-half of the pigs in treatment 1 received only 100 mg. of elemental iron while the others received 150 mg. as in trial II. These pigs were weaned at 56 days of age and data are presented on weight gains from birth to 56 days of age.

Results and Discussion

Trial I. The effect of treatment on weight gain, hemoglobin level, and mortality is presented in table 1. Injecting peptonized iron intramuscularly at 1 day of age caused a high mortality, 37%, compared to 6 and 7% for the other two treatments. Most of the mortality occurred during the 24 to 48 hours immediately after the initial injection. Symptoms were not observed prior to death and post mortem examination did not reveal the cause of death. There was no death loss following the second injection at 21 days of age. The peptonized iron injection did not maintain the hemoglobin level so that at 21 days of age it was significantly less than the other two treatments. A second injection at this time caused a rise in the hemoglobin level of these pigs.

Significantly higher hemoglobin levels at 10 and 21 days of age were obtained in the pigs injected with the iron-dextran solution. Hemoglobin level of these pigs remained quite constant during the first 3 weeks and dropped from 9.93 to 8.90 gm. per 100 ml. of blood between 21 and 28 days of age. The hemoglobin level of pigs given the oral pill decreased from 11.03 at birth to 8.39 gm. at 10 days of age. Additional pills at 10 and 21 days of age maintained the level at approximately 8 gm. for the remainder of the trial.

Body weight was not significantly different between treatments. How-

ever, the pigs that received the iron-dextran injection were heavier at 28 days of age. This increase in gain was noted at 10 days of age and magnified with increasing age.

Trial II. Table 2 summarizes the weight, mortality and hemoglobin data. There was not any significant treatment difference in weight gains or mortality in this trial. However, in the pigs used for hemoglobin determina-

TABLE 1. EFFECTS OF THREE METHODS OF IRON ADMINISTRATION ON WEIGHT GAINS AND HEMOGLOBIN LEVELS OF PIGS

Treatment and age at treatment	Oral iron 1, 10, and 21 days	Iron-dextran 1 day	Peptonized iron 1 and 21 days
	Data on pigs used for hemoglobin study		
No. of pigs	24	23	15
Mortality, %	0	4	38
Av. initial wt., lb.	2.8	2.9	3.0
Av. 10 day wt., lb.	6.5	7.1	6.9
Av. 21 day wt., lb.	11.2	12.2	11.7
Av. 23 day wt., lb.	14.1	15.2	14.7
Av. total gain, lb.	11.3	12.4	11.7
Hemoglobin level, gm. %			
Birth	11.03	10.43	10.01
10 days	8.39	10.34[a]	8.38
21 days	7.98[b]	9.93[a]	6.41
28 days	8.00	8.90	7.76
	Weight data of all pigs		
No. of pigs	64	63	42
Mortality, %	6	7	37
Av. initial wt., lb.	2.9	2.9	3.0
Av. 28 day wt., lb.	15.2	16.0	15.2
Av. total gain, lb.	12.3	13.1	12.2

[a] Significantly greater than two least values ($P<.01$).
[b] Significantly greater than least value ($P<.01$).

tion slightly greater weight gains were obtained in treatment 1 which also maintained the higher hemoglobin levels.

The hemoglobin content declined during the first 2 days regardless of the iron treatment. Rydberg *et al.* (1959b) expressed the belief that the hemopoietic centers in pigs may not become hyper-active until the hemoglobin content has reached a certain minimum level which then triggers an activating mechanism associated with these centers. The pigs which received an iron injection providing 150 mg. of elemental iron showed a rise in blood hemoglobin by 7 days of age, reaching a peak at 14 days. A gradual decline occurred from 14 to 28 days. At 7, 14, 21, and 28 days the hemoglobin level of this treatment was significantly greater than the hemoglobin level of pigs injected with 100 mg. of elemental iron at 7 days of age.

Pigs receiving iron-dextran providing 150 or 100 mg. of elemental iron during the first day of life showed little difference in hemoglobin levels during the first 7 days. However, a higher peak level of hemoglobin was observed at 14 days in pigs given the higher level of iron. A sharper decline in hemoglobin level occurred during the second to the third week in those

TABLE 2. EFFECT OF INTRAMUSCULAR IRON-DEXTRAN ON WEIGHT GAINS AND HEMOGLOBIN LEVELS OF PIGS

Treatment no.	1	2	3
Elemental iron per treatment	150 mg.	100 mg.	100 mg.
Age at treatment	1 day	7 days	1 and 21 days
	Data on pigs used for hemoglobin study		
No. of pigs	23	22	21
Mortality, %	4	8	7
Av. initial wt., lb.	3.2	3.3	3.2
Av. 7 day wt., lb.	5.9	6.2	6.1
Av. 14 day wt., lb.	9.4	9.3	9.4
Av. 21 day wt., lb.	12.4	12.4	12.2
Av. 28 day wt., lb.	15.7	15.5	15.3
Av. total gain, lb.	12.5	12.2	12.1
Hemoglobin level, gm. %			
Birth	9.90	10.66	10.86
1 day	8.86	8.94	9.13
2 days	8.57	8.42	8.98
7 days	9.66[a]	6.04	9.58[a]
14 days	11.26[b]	10.08	10.62
21 days	10.97[c]	9.64	8.91
28 days	10.54[b]	9.01	10.58[b]
		Weight data of all pigs	
No. of pigs	36	35	35
Mortality, %	6	8	9
Av. initial wt., lb.	3.3	3.4	3.2
Av. 28 day wt., lb.	15.7	15.8	15.6
Av. total gain, lb.	12.4	12.4	12.4

[a] Significantly greater than least value ($P<.01$).
[b] Significantly greater than least value ($P<.05$).
[c] Significantly greater than two least values ($P<.05$).

pigs that received the 100 mg. level of iron so that at 21 days a significant difference existed between treatments. A second injection of 100 mg. of iron at 21 days resulted in a rise in hemoglobin and a level at 28 days equal to that of pigs that received the one treatment of 150 mg. of iron. Barber *et al.* (1958) observed that a second iron injection at 14 days resulted in a further rise in blood hemoglobin with no difference shown in weight gains.

The hemoglobin declined to 6.04 gm. per 100 ml. of blood at 7 days of age in pigs that did not receive any iron treatment the first week. An

iron injection providing 100 mg. of elemental iron at 7 days of age caused a sharp rise in hemoglobin with the highest level obtained at the 14-day sampling period. A slight decline then occurred although at 21 days of age these pigs showed slightly higher hemoglobin levels than did those pigs receiving a like amount of iron shortly after birth.

Trial III. Intramuscular injections at 1 day of age of iron-dextran containing 100 or 150 mg. of elemental iron or 100 mg. at 7 or at 1 and 21 days of age resulted in no significant difference in 56-day weights of pigs (table 3). The heavier 56-day weight of the pigs which received the 100 mg. of iron at 1 day of age is attributed, at least in part, to the heavier initial weight of these pigs resulting from the loss of some of the smaller pigs on this treatment.

TABLE 3. EFFECT OF INTRAMUSCULAR IRON-DEXTRAN ON WEIGHT GAINS OF PIGS WEANED AT 56 DAYS OF AGE

Treatment no.	1a	1b	2	3
Elemental iron per treatment	150 mg.	100 mg.	100 mg.	100 mg.
Age at treatment	1 day	1 day	7 days	1 and 21 days
No. of pigs	14	13	36	34
Av. initial wt., lb.	3.0	3.5	3.3	3.3
Av. 56 day wt., lb.	28.0	30.7	28.6	28.7
Av. total gain, lb.	25.0	27.2	25.3	25.4

The results of trials II and III do not indicate any real difference in efficacy of the various iron-dextran treatments. All appear to be effective in preventing baby pig anemia. The injection of 150 mg. of iron produced the higher hemoglobin level that was maintained over a longer period. The possibility exists that body weight may be related to hemoglobin level. Treatment during the first day of life is advantageous in that pigs are often handled at that time to obtain birth weights, to ear notch for identification and to clip needle teeth.

Summary

Injecting baby pigs during the first day of life with an iron-dextran solution providing 100 mg. of elemental iron resulted in higher hemoglobin values at 10, 21, and 28 days of age and heavier pigs at 28 days than when an oral iron pill was administered at 1, 10, and 21 days or when 250 mg. of peptonized iron was injected intramuscularly at 1 and 21 days of age.

Intramuscular iron-dextran injections during the first day of life did not completely prevent the decline in blood hemoglobin during the first two days; however, at 7 days of age these pigs had hemoglobin levels significantly higher than pigs not treated until 7 days of age. An injection

providing 150 mg. of elemental iron resulted in higher hemoglobin values at 14 and 21 days than a 100-mg. injection. A second 100-mg. injection at 21 days of age gave comparable hemoglobin values at 28 days of age. Pigs that received an injection providing 100 mg. of iron at 7 days of age had hemoglobin values that were higher at 21 days but lower at 28 days than those of pigs that received 100 mg. of iron at 1 and again at 21 days of age. These three iron-dextran treatments all produced similar weight gains at 28 days of age.

Pigs that received iron-dextran providing either 100 mg. or 150 mg. of elemental iron and injected at 1 or 7, or 1 and 21 days of age did not significantly differ in body weight at 56 days of age.

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ESTROGENIC ACTIVITY IN DEHYDRATED AND SUNCURED FORAGES

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FORAGE meals are widely used in mixed feeds as a source of energy, vitamins, minerals, and protein. These meals also contain factors such as estrogens (Bickoff *et al.*, 1957) and saponins (Lindahl *et al.*, 1957) which have biological effects, and unidentified factors which may affect growth, reproduction, and lactation (Kohler, 1953).

Interest in the estrogenic activity of forage plants has increased in recent years for several reasons. First, it is well established that infertility in breeding animals can result from excessive ingestion of forages rich in estrogenic compounds (Bradbury and White, 1954). Second, the "spring flush", leading to increased milk production in dairy cows, may be due to a higher estrogen content of rapidly growing forage (Cheng *et al.*, 1953). Third, the demonstration that feed efficiency and rate of growth of cattle and sheep are improved by synthetic estrogens suggests that feeding of plants rich in natural estrogens may also affect growth rate and carcass quality. Recent work has shown that animals are less responsive to stilbestrol when the basal diet contains estrogen-rich forage (Matsushima, 1959).

In connection with studies in this laboratory on the occurrence of the plant estrogen, coumestrol, in legumes (Lyman, 1959), we have surveyed a number of commercially dehydrated alfalfa, clover, and grass meals and also suncured forages for estrogenic activity. These data were accumulated during a search for forages of high estrogen content for fractionation and analytical studies. This study revealed wide variation in the estrogenic activity of commercial meals.

Materials and Methods

A number of dehydrated alfalfa meals and some dehydrated clover and grass samples from commercial dehydrators in various parts of the U. S. were assayed, and also some sun-cured meals. Details of the method routinely employed have been published (Bickoff *et al.*, 1959). Briefly, it consists of the following steps: An acetone extract of the forage is added to the basal ration and fed to immature female mice, 19 to 21 days of

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age, caged in groups of five. The test is continued for a period of 4 to 6 days until an average of 10 gm. of diet is consumed per mouse. The mice are then sacrificed and the freshly excised uteri are weighed. The uterine weight increase for a given equivalent weight of dried forage is used as a measure of the estrogenic activity of the forage samples.

Results and Discussion

In earlier work at Purdue University (Pieterse and Andrews, 1956) and Iowa Agricultural Experiment Station (Cheng *et al.*, 1953) estrogenic activities of forages were expressed in terms of stilbestrol equivalencies per

TABLE 1. DEMONSTRATION OF PRESENCE OF AN ESTROGEN POTENTIATOR IN ALFALFA MEAL

Equivalent amt. of meal fed	Supplemental level of coumestrol fed (mg./mouse)					
	0	0.2	0.3	0.4	0.5	0.6
gm./mouse	Average uterine response (mg.)					
0	9.0	13.5	21.3	33.5	55.7	82.9
4	9.0	37.0	72.9	66.9	....	118.7
8	9.3	32.5	50.3	57.7	101.1	63.7

pound of feed, and a recent Canadian report (Kitts *et al.*, 1959) continues this practice. However, a recent report from Purdue (Stob *et al.*, 1957) presents only uterine weight responses to a given amount of alfalfa extract. These workers point out that the estrogenic compound(s) present in forages do not necessarily have the same degree of oral potency as diethylstilbestrol and that the laboratory ration used for establishment of the sensitivity of the mouse uterus to diethylstilbestrol is entirely different from the laboratory ration containing the alfalfa extracts. The extracts are naturally quite crude and may contain substances which either enhance or interfere with normal biological response.

Pieterse and Andrews (1956) also pointed out that under some conditions, farm animals, especially ruminants, might ingest more potent estrogen from fresh forage than mouse uterine weight assays would indicate, if assays are based only on dried samples, as has been the case with most of the reported studies. Substantial loss of estrogenic activity does appear to occur during the drying operation (Bickoff *et al.*, 1959). Recently van Erkelens and van der Veen, (1958) reported that hay-making also reduces estrogenic activity.

Kitts *et al.* (1959) have shown that mice are reluctant to eat test diets containing the forage extract. This is also the case in our laboratory. In this connection Umberger and Gass (1959), in developing a bioassay for

TABLE 2. DEMONSTRATION OF PRESENCE OF AN ESTROGEN INHIBITOR IN ALFALFA MEAL

Equivalent amt. of meal fed	Supplemental level of coumestrol fed (mg./mouse)	
	none	0.3
gm./mouse	Average uterine response (mg.)	
0	9.0	31.1
5	10.4	13.4
10	9.2	9.3

estimation of estrogenic residues in edible tissues of domestic animals treated with estrogens, pointed out that the fat content of the basal diet affects the uterine response. Umberger *et al.* (1958) also recommended that control diets contain comparable tissues from animals which did not receive stilbestrol treatment, in order to balance out possible tissue interference with the assay (1958). In an analogous manner, we attempted to incorporate an extract of alfalfa meal which produced no estrogenic response into the basal diet to serve as a control. However, when known amounts of coumestrol were added to such a basal diet, unexpected results were obtained. With some meals, the extract acted as an estrogen potentiator (table 1), giving no response in the absence of added coumestrol, but increasing the response of added coumestrol. Extracts of certain other meals acted as estrogen inhibitors, depressing the response of added coumestrol. It thus appears that estrogenic response obtained when a crude forage extract is assayed represents a summation of effects of the estrogen inhibitors and potentiators, together with that of the estrogenic compounds in the forage (table 2). Furthermore, since the curve of response to graded levels of forage extract does not always have the same slope as those of response to stilbestrol or coumestrol, variable results will be obtained when different amounts of extract are evaluated. This was demonstrated with forage extracts by Payne (1953) and is illustrated by our results in table 3. In this case, the apparent coumestrol content should have been the same instead of increasing with dosage. In a related study,

TABLE 3. BIOASSAY OF ALFALFA MEAL

Equivalent level of meal per mouse	Number of mice	Average uterine wt.	Standard deviation of uterine wt.	Coumestrol equivalents
gm.		mg.		mg./kg.
3	23	15.1	±4.2	48.6
4	20	23.1	±9.9	56.8
5	20	34.5	±16.8	68.0

Ershoff (1956) reported that the deleterious effects of estrogen feeding on ovarian development in the immature rat could be largely counteracted by the concurrent feeding of dried alfalfa, thus suggesting the presence of an estrogen inhibitor. He also reported that commercial samples of alfalfa meal varied from being markedly active to virtually inert in regard to their effect on counteracting added estrogen. In order to minimize this variable, all meals in the present study were tested at the same level (equivalent to 8 gm./mouse). To obtain some measure of the precision of the bioassay, a study was made of variability of results obtained from four or five replicate cages (each containing five mice), for a representative alfalfa and clover meal as well as for coumestrol and stilbestrol. In addition, estimates were obtained of the standard error of the difference of responses from two cages of animals on the same diet as shown in table 4. These measures of

TABLE 4. STATISTICAL STUDY OF VARIABILITY

Diet	Standard error of difference of two cage means	95% confidence interval of difference of two cage means
	%	%
Stilbestrol	8	25
Coumestrol	15	57
Forage	26	72

dispersion might be used as a criterion in judging the importance of differences between single-cage assays obtained with different forage meals using five mice per cage.

Of a large number of commercially dehydrated meals prepared in California, many showed no estrogenic activity under conditions of our mouse assay (table 5). However, many of these contained small amounts of coumestrol, as determined chromatographically (Lyman *et al.*, 1959), and estrogenic activity could be demonstrated if greatly increased quantities of extract were fed (Bickoff *et al.*, 1959). On the other hand, a number of samples obtained from Nebraska, Ohio, and Pennsylvania were markedly estrogenic. The activity varied widely and did not appear to be correlated with stage of maturity, variety, or number of cuttings. Pieterse and Andrews (1956) have reported on the estrogenic activity of four dehydrated alfalfa samples and showed a considerable variation between them although none was as highly estrogenic as some reported in the present communication. More recently, Stob *et al.* (1957) have assayed 56 strains of several varieties of alfalfa and have found a very wide variation in the estrogenic activity within this plant species.

Of a number of commercially dehydrated and sun-cured clover meal samples studied, all but one showed estrogenic activity, the one exception being a sample of white clover meal (table 6). Little or no estrogenic

TABLE 5. ESTROGENIC ACTIVITY IN DEHYDRATED ALFALFA MEAL [a]

Where grown	Dehydrator	Variety	Cutting	Season	Stage of maturity	Average uterine weight
						mg.
California	C-1	Calif. common	5th	1956	Full bloom	10.1
	"	"	5th	1956	Bud, very leafy	12.5
	"	"	4th	1956	Bud, very leafy	11.4
	"	"	1st	1958	.....	16.5
	"	"	6th	1958	Early bloom	11.5
	"	"	1st	1959	.....	11.1
	"	"	2nd	1959	.....	12.3
California	C-2	Calif. Common	...	1957	.....	9.6
	"	"	...	1957	.....	9.5
	"	"	...	1958	.....	11.1
	"	"	...	1958	.....	9.1
	"	"	...	1958	.....	8.9
	"	"	...	1959	.....	18.5
California	C-3	.....	...	1959	.....	12.0
	"	.....	...	1959	.....	9.5
	"	.....	...	1959	.....	10.1
	"	.....	...	1959	.....	11.2
California	C-4	.....	...	1955	.....	9.8
	"	.....	...	1958	.....	9.7
California	C-5	.....	2nd	1959	.....	8.4
Kansas	K-1	.....	...	1958	.....	16.4
Nebraska	N-1	.....	...	1958	.....	9.5
Nebraska	N-2	.....	...	1958	.....	24.8
	"	.....	...	1958	.....	72.9
Nebraska	N-3	Neb. Common	2nd	1958	Full bloom	64.4
	"	"	3rd	1958	" "	36.1
	"	Ranger	4th	1958	Bud	11.1
	"	"	4th	1958	"	12.0
Nebraska	N-4	Ranger	4th	1957	Bud	12.4
Ohio	O-1	.....	...	1958	.....	51.0
Ohio	O-2	Home-grown Kansas Common	1st	1958	Stemmy	29.7
Ohio	O-2	Ranger	3rd	1958	Bud	15.1
	"	"	2nd	1958	¼ bloom	25.9
	"	"	1st	1958	Prebud	10.2
Pennsylvania	P-1	.....	...	1958	.....	18.3

[a] Assayed by feeding the equivalent of 8 gm. alfalfa per mouse in 10 gm. diet.

activity was obtained in a group of dehydrated grasses (table 7) or in dried juice concentrates prepared from a variety of forage materials (table 8).

A series of sun-cured alfalfa meal samples prepared in Arizona showed a remarkably wide fluctuation in estrogenic activity, apparently correlated

TABLE 6. ESTROGENIC ACTIVITY IN DEHYDRATED CLOVERS [a]

Where grown	Dehydrator	Variety	Cutting	Season	Stage of maturity	Average uterine weight
						mg.
Kansas	K-1	White	1st	1954	Prebloom	9.8
	K-1	White	...	....	.....	14.0
	K-1	Red	2nd	1954	Early bloom	63.5
Oregon	Sun-cured	Red	1st	1958	Bloom	58.2
California	C-6	Ladino	...	....	.....	65
	Sun-cured	Strawberry	...	....	.....	21.2
Australia	Sun-cured	Subterranean	...	1956	.....	58.6

[a] Assayed by feeding the equivalent of 8 gm. alfalfa per mouse in 10 gm. diet.

with the season of year that the plants were cut. These plants all consisted of field-dried samples of African variety. They were taken from different fields so that they did not represent consecutive cuttings from plants grown in one location. Rather, they represented average cuttings during the month period involved, cut at between ½ and ¾ bloom stage (table 9).

TABLE 7. ESTROGENIC ACTIVITY IN DEHYDRATED GRASSES [a]

Where grown	Dehydrator	Variety	Cutting	Season	Stage of maturity	Average uterine weight
						mg.
Arkansas	A-1	Cereal-grass Balboa rye	1st	1958	8-week old	10.1
Washington	W-1	Common rye grass	1st	1958	Leafy, some stems	10.4
	W-1	" "	...	1957	.....	7.3
	W-1	Reed Canary	2nd	1958	Leafy	10.4
	W-1	" "	...	1957	.....	23.2
Washington	W-2	Orchard grass 74.5% Alta fescue 13.0% Ladino clover 12.5%	6th	1958	Leafy 14–16 in.	12.8
British Columbia	BC-1	Common rye grass	...	1958	.....	9.1
British Columbia	BC-1	Orchard and ladino	8th	1958	Leafy 10–12 in.	8.5
Ontario, Canada	OC-1	Orchard	3rd	1958	.....	12.2

[a] Assayed by feeding the equivalent of 8 gm. alfalfa per mouse in 10 gm. diet.

TABLE 8. ESTROGENIC ACTIVITY IN DRIED JUICE CONCENTRATES[a]

Forage	Average uterine weight
	mg.
Wheat	8.3
Corn	7.9
Colza	8.3
Barley	7.4
Oats	10.2
Rye	6.2
Alfalfa	9.6
Control	9.2

[a] Assayed by feeding the equivalent of 8 gm. dried forage concentrate per mouse in 10 gm. diet.

The higher estrogen activity of alfalfa meals produced in other states compared with California might be attributed to different varieties, cultural practices, stage of growth, or season of year at which the plants were harvested. Other possibilities may include loss of estrogen during dehydration (Bickoff *et al.*, 1959) or subsequent storage of the meal. Swierstra (1958) has reported that estrogenic activity is completely lost from alfalfa and ladino clover meals after 6 months' storage at room temperature. Our storage studies at room temperature (table 10) confirm the fact that the estrogen may be unstable during storage in some meal samples, although the rate of loss under our conditions is not as great as that reported by Swierstra. He also points out that estrogenic activity in red clover is much better retained during storage than is that of alfalfa or ladino clover and suggests that this difference may be due to different estrogens present in the various forages—i.e., genistein and related isoflavones predominating in the red clover, whereas coumestrol is the predominant estrogen in alfalfa and ladino clover. It has been demonstrated earlier that coumestrol is more labile to alkali degradation and may also be more susceptible to oxidative degradation than the isoflavones (Bickoff *et al.*, 1959).

TABLE 9. ESTROGENIC ACTIVITY IN SUNCURED ALFALFA[a] GROWN IN ARIZONA AND CUT AT ½ TO ¾ BLOOM

Dates of growth 1957–58	Average uterine weight
	mg.
11/9–12/6	11.2
12/7–1/4	10.8
1/5–2/5	102.6
2/6–3/5	41.3
3/6–4/3	15.0
4/4–5/5	20.1

[a] Assayed by feeding the equivalent of 8 gm. alfalfa per mouse in 10 gm. diet.

The results show the need for good chemical methods so that true estrogen content can be measured without interference from potentiators and inhibitors. Further, research is urgently needed to determine the nature of the potentiators and inhibitors and to determine their importance in practical animal production.

TABLE 10. STABILITY OF ESTROGEN-LIKE COMPOUNDS IN ALFALFA [a] AND LADINO CLOVER MEALS

Sample designation	Mean uterine weight		Time elapsed
	First assay	Second assay	
	mg.	mg.	mo.
Alfalfa—A	97	70	9
—B	84	43	5
—C	47	52	5
—D	59	19	17
—E	70	56	9
Ladino clover—A	36	16	10
—B	82	41	11
—C	83	110	11
—D	82	71	11

[a] Assayed by feeding the equivalent of 8 gm. forage samples per mouse in 10 gm. diet.

Summary

A large number of dehydrated forage samples were obtained from various parts of the U. S. and assayed for apparent estrogen content. Also included were a number of suncured alfalfa, clover, and grass samples. Very large variations in apparent estrogen content were found between samples. These may be partially attributed to geographical location, differences in variety, cultural practice, stage of growth, or season of year at which the plants were harvested. Other factors shown to be involved are losses of estrogen during dehydration or subsequent storage of the meal. A very important factor appears to be the presence in meals of estrogen potentiators and inhibitors in differing proportions.

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A SIMPLE, EFFECTIVE TYPE OF MINIATURE SILO FOR CONDUCTING SILAGE INVESTIGATIONS [1]

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THE use of feed-lot silos for conducting silage investigations poses many problems of experimental technique. Even with the most elaborate feed-lot type silo set-up only a very small percentage of the inter-relationships which exist between the various factors affecting silage preservation and quality can be studied within any one test.

Workers over the years have attempted to use various types of miniature silos in an effort to overcome some of the limitations of the feed-lot silo for silage research purposes. Containers such as test tubes (Allen *et al.*, 1937a), glass jars (Garber and Odland, 1927; Autrey *et al.*, 1947), glass cylinders (Archibald, 1946), metal cans (Nevens, 1933) and small concrete and wooden structures (Neidig, 1918; Allen *et al.*, 1937a; Allen *et al.*, 1937b) have been used as miniature silos with varying degrees of success. In general, the suitability of such containers have depended largely on the degree to which air was excluded from the silage material. However, no completely satisfactory method for the exclusion of air was reported by the above workers and varying degrees of spoilage were experienced in most instances.

Experimental

Prior to conducting a silage study reported elsewhere (Cullison, 1948), an effort was made to develop a satisfactory arrangement for permitting the escape of gases from a miniature silo and excluding air from the silage material. Initially it was thought that a valve such as described by Babcock and Russell (1901) and Peterson *et al.* (1925), consisting of a U-tube trap filled with oil or mercury, might serve for this purpose. However, in attempts to use such a valve on a trial basis, it did not prove satisfactory for the purpose in question.

It was decided following further study that an ordinary Bunsen valve such as is described subsequently offered the most promise for meeting this need. Such a valve has long been in use around chemical and biological laboratories. However, in so far as this worker has been able to determine, its application to the operation of a miniature silo has not been reported previously.

[1] The work on which this paper is based was conducted at the Alabama Polytechnic Institute while the author was a staff member of the Animal Husbandry Dept. at that institution and made up one phase of his Ph.D. thesis research conducted *in absentia* under the supervision of the Graduate School of the University of Illinois.

The miniature silo used in this study consisted of a two-quart glass jar equipped with a one-hole No. 12 rubber stopper carrying a short piece of glass tubing to which a valve of the above type was attached. The valve was made by placing a small cleancut slit longitudinally in the side of a short piece of rubber tubing with a razor blade. A glass plug was then placed in one end of the rubber tubing with the other end attached to the glass tubing leading through the stopper in the jar. A diagram of the stopper and valve arrangement is shown in figure 1.

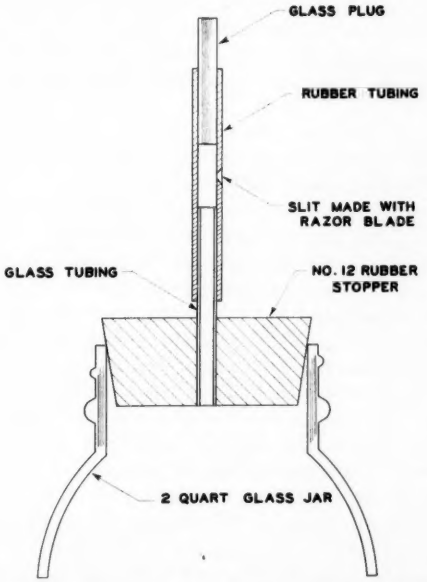

Figure 1. Stopper and valve arrangement used with miniature silos.

A total of 24 miniature silos so equipped were used in this study in which sweet sorghum was ensiled at three different stages of maturity each with four different treatments and for storage periods of two different lengths. The sweet sorghum was run through a regular silage chopper, treated, and packed tightly into the jars, which were then promptly closed with a valve-equipped stopper. The different treatments involved included (1) control; (2) 5 lb. urea per ton; (3) 10 lb. urea per ton; and (4) 80 lb. cottonseed meal per ton. The two storage periods were approximately 4 and 9 months, respectively. Three of the silages produced in the 24 miniature silos were directly comparable from the standpoint of ensiling treatment and length

of storage period with silages stored in different sections of a trench-type, feed-lot silo. Hence, it was possible to compare the composition of silages produced in the miniature silos with similar silages produced under regular trench-type silo conditions.

Results and Discussion

Silage which was quite normal in every apparent respect was produced in each of the 24 miniature silos. In only one of these silos was there the slightest sign of mold formation and this was only on the very top surface.

The results of detailed chemical analyses of certain of the silages involved are presented in table 1 for comparison purposes. The analytical procedures followed in making the various determinations are as reported by Cullison (1948).

It may be noted from the table that the silages from the miniature silos are quite similar in composition to the respective silages of the feed-lot silo. Where there is a sizable difference the difference is, in almost every instance, in favor of the silage from the miniature silo in so far as the usual standards of silage quality are concerned. This would suggest that conditions are even more favorable for good silage production in a miniature silo, such as was used in this study, than in a trench-type feed-lot silo. Confirming this observation is the fact that there were practically no differences in the composition of the silages stored in miniature silos for 4 months as compared to similar silages stored for 9 months. In other words, there seemed to be very little, if any, deterioration in the various silages of the miniature silos as the result of an extra five month's storage.

The results of dry matter loss determinations on the different silages under the various conditions are also in line with the above observations. Dry matter losses from the silages in the feed-lot silo as measured by the buried sack method averaged 19.1% during storage periods ranging from 3–5 months as compared to average dry-matter losses from corresponding silages in miniature silos of 5.9% and 6.3% during storage periods of 4 and 9 months, respectively.

One cause of this difference could be in the loss of soluble constituents from the feed-lot silo through drainage of silage juices. There was some loss of dry-matter in this manner, although it did not appear to be excessive. Also, there were indications of more extensive fermentation in the feed-lot silo. These silages were quite warm for several months after the silo was filled, whereas there was no apparent fermentation in the silages of the miniature silos after the first two weeks.

One might reason, in view of the above, that the conditions of a miniature silo are too ideal to be typical of usual feed-lot silo conditions for ensiling purposes. However, it would seem that some standard set of conditions for conducting silage research would be desirable and those approaching the ideal would be a sound basis on which to work.

TABLE 1. CHEMICAL COMPOSITION OF THREE DIFFERENT SILAGES STORED IN FEED-LOT SILO FOR FOUR MONTHS AND IN MINIATURE SILOS FOR FOUR AND NINE MONTHS, RESPECTIVELY

Ensiling treatment, type of silo, and length of storage	Dry matter, %	Crude protein, %	Reducing sugars, %	Carotene, mcg./gm.	Ammonia nitrogen, mg./100 gm.	pH	In ml. of N/10 acid per 100 gm. of silage: Total free and combined acidity	Total free acidity	Free and combined lactic acid	Free and combined acetic acid	Amino acids
Untreated sorghum											
Feed-lot silo-4 mo.	21.43	1.31	2.02	7.9	17.3	3.85	319.2	228.2	115.7	124.9	78.6
Miniature silo-4 mo.	22.77	1.32	3.04	7.8	13.8	3.58	312.6	238.6	172.8	75.8	64.0
Miniature silo-9 mo.	21.26	1.34	1.93	5.8	18.7	3.66	323.2	246.2	173.7	85.9	63.6
Urea-treated sorghum											
Feed-lot silo-4 mo.	20.43	3.64	.11	9.2	303.1	4.45	538.4	274.4	203.6	287.2	47.6
Miniature silo-4mo.	21.46	2.73	2.94	11.8	49.8	3.62	336.1	243.8	200.9	78.6	56.6
Miniature silo-9 mo.	21.73	2.79	2.48	8.8	56.1	3.75	343.2	246.0	201.8	84.2	57.2
CSM treated sorghum											
Feed-lot silo-4 mo.	23.92	2.60	1.84	12.0	36.8	4.05	363.4	221.5	124.8	123.0	115.6
Miniature silo-4 mo.	23.67	2.59	1.54	1.2	32.8	3.85	396.6	271.2	191.7	103.1	101.8
Miniature silo-9 mo.	25.03	2.72	1.88	7.2	38.7	3.88	440.3	286.1	204.9	108.8	126.6

It might be felt by some that the use of a container such as a two-quart jar would not be suitable as a miniature silo since the heat losses from such a small container at the time of ensiling would be so great the temperature level within the silage material would not be comparable to that within a larger silo. While such is a possibility, this could be overcome by substituting an insulated container in the place of the two-quart glass jar used in this study. The use of a storage unit in which the temperature could be controlled would be another possible solution to this problem.

Summary

A study of the use of a valve consisting basically of a piece of rubber tubing with a slit in the side for permitting the escape of fermentation gases from and preventing the entrance of air into a miniature silo is reported. Such a valve, used in conjunction with two-quart jars equipped with rubber stoppers, from all indications provided quite favorable ensiling conditions and resulted in the production of excellent silage.

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CROSSBRED AND PUREBRED DAMS FOR THE PRODUCTION OF SLAUGHTER CALVES [1]

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TESTS at various stations have shown that crossbred British x British or Brahman x British calves are heavier at birth and at weaning than purebreds. The crossbred calves also grade higher and have a higher dressing percentage. A limited number of studies have been conducted to determine the advisability of retaining these crossbred females in the breeding herd.

Lush *et al.* (1930) reported that Brahman x Hereford crossbred calves were heavier than purebred Herefords at weaning. Calves produced by backcrossing Hereford bulls on the crossbred dams were heavier than the F_1 calves at weaning. Rhoad and Black (1943) found that when Brahman x Angus cows were bred to Angus bulls, the calves produced were lighter than the crossbred dams at birth but heavier at six months of age. Similar results were reported by Baker and Black (1950). Baker (1949) reported that calves produced by mating Angus bulls to Brahman x Angus cows were not as heavy at maturity as their dams. McCormick and Southwell (1957) found that calves from crossbred Brahman x Hereford cows were 18% heavier at weaning than calves from Angus x Hereford dams. The average slaughter grade of the Brahman x Hereford calves was slightly higher, but the difference was not significant. The carcass grades and the dressing percentages of the two groups of calves were not different. Warwick (1953) summarized experiments comparing the performance of Brahman x British and British cows. This summary showed that the calves from the crossbred cows were 83 lb. heavier at weaning than those out of cows of British breeding. Damon *et al.* (1959) found that crosses among Brahman and other breeds of cattle were heavier than purebreds at weaning but showed little advantage in slaughter calf grades. They stated that the advantage was most pronounced when the Brahman breeding was in the females.

The purpose of this study was to compare crossbred Brahman x Angus, Brahman x Hereford, Hereford x Angus and purebred Angus cows for the production of slaughter calves. The birth and 210-day weights, slaughter and carcass grades and dressing percentages of the calves were used as measures of cow performance.

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Experimental Procedure

One hundred and sixty-seven calves, which were sired by the same Shorthorn bull and out of Angus, Brahman x Angus, Hereford x Angus and Brahman x Hereford cows, were produced at the Coast Experiment Station, Summerville, South Carolina during the period 1954–1958. The Brahman x Hereford dams originated at the College Station, Clemson, South Carolina, while the cows in the other groups were produced at the Coast Station. All of the crossbred cows had been produced in a previous breeding study, Godbey *et al.* (1959), and retained for use in this experiment.

The cows were bred to produce their first calves at three years of age and were maintained as a unit under normal management procedures. The

TABLE 1. NUMBER OF CALVES PRODUCED, BY YEARS AND BREEDING GROUPS

Breeding group[a]	Number of calves in year—					Total number
	1954	1955	1956	1957	1958	
S x BA	5	12	11	9	7	44
S x BH	0	3	10	11	10	34
S x A	5	10	10	10	7	42
S x HA	6	12	10	10	9	47
Total	16	37	41	40	33	167

[a] A=Angus; B=Brahman; H=Hereford; S=Shorthorn.

breeding season each year extended over a 90-day period with most of the calves being dropped between January 1 and April 1. Creep feed was available for the calves at all times.

The calves were weighed at birth and at 210±3 days of age. The average daily gain from birth to the date of final weight was used in determining the adjusted 210-day weight for each calf. Immediately after weaning the calves were delivered to a local packing house where they were weighed and graded. After slaughter the carcasses were graded and dressing percentages determined. Three graders working independently scored the animals and the carcasses. These scores were averaged to determine the slaughter and carcass grade. Dressing percentage was calculated by using the cold carcass weight and the sales weight. The numbers of calves providing data for this study are shown in table 1.

The Adjustment of Data. Least squares analysis was used to adjust the data for differences due to sex and years. The means were adjusted to a 1957 steer basis. Estimates of the effect of breeding, year of birth and sex with appropriate standard errors are shown in table 2. These estimates show that the steers were 2.85 lb. heavier than the heifers at birth and 41.27 lb. heavier at 210 days of age. Sex did not have a significant effect on slaughter grade, carcass grade or dressing percentage. No adjustment

TABLE 2. LEAST SQUARES ESTIMATES OF THE INFLUENCE OF BREEDING, YEAR OF BIRTH AND SEX ON THE TRAITS STUDIED

	Birth weight		210-day weight		Slaughter grade		Carcass grade		Dressing percentage	
S x A	—2.49	1.79[a]	—59.46	8.24	0.17	.54	—.28	.44	0.27	.49
S x HA	5.61	1.74	—44.41	7.80	0.49	.52	1.04	.42	—.19	.47
S x BA	0.00		0.00		0.00		0.00		0.00	
S x BH	—1.61	1.94	—19.86	8.96	—.84	.58	—.55	.48	1.40	.53
1954	—6.04	2.48	—46.87	11.39	—2.37	.74	—3.96	.61	—1.79	.67
1955	—5.50	1.91	—21.39	8.79	—2.33	.57	—4.27	.47	0.23	.52
1956	—2.60	1.83	—18.15	8.42	—1.02	.55	—2.38	.45	—.16	.50
1957	0.00		0.00		0.00		0.00		0.00	
1958	.08	1.94	—13.82	8.94	—.97	.58	—1.16	.48	1.93	.53
Heifers	—2.85	1.30	—41.27	5.98	—.71	.39	—.52	.32	—.13	.35
Steers	0.00		0.00		0.00		0.00		0.00	

[a] Standard ± errors are shown in the second column for each estimate.

was made for age of dam since each cow was bred to produce her first calf as a three-year old while on this test. With the exception of 1954, some cows of the same age were in each breeding group.

The adjusted means for the traits studied are shown in table 3.

Results and Discussion

Analyses of variance of the traits studied showed that there were highly significant differences between the breeding groups in birth weight, 210-day weight and carcass grade. The differences in dressing percentage were significant at the .05 level. Differences in slaughter grade were not significant. To determine the differences between any two breeding groups the constants shown in table 2 with appropriate standard errors were used. Standard errors for comparisons other than those shown in the table were computed, using the elements of the inverse matrix and the variance. The least significant difference technique was used in determining the significance of the differences shown in table 4.

The adjusted birth weight of the calves varied from 67.29 lb. for those out of Angus dams to 75.39 lb. for those out of the crossbred H x A cows.

TABLE 3. AVERAGE ADJUSTED BIRTH WEIGHT, 210-DAY WEIGHT, SLAUGHTER GRADE, CARCASS GRADE AND DRESSING PERCENTAGE OF CALVES

Breeding group	Weight (lb.)		Grade[a]		Dressing percentage
	Birth	210-day	Slaughter	Carcass	
S x A	67.29	498.01	15.74	16.23	58.65
S x HA	75.39	513.06	16.06	17.55	58.19
S x BA	69.78	557.47	15.57	16.51	58.38
S x BH	68.17	537.61	14.73	15.96	59.78

[a] 8–12 choice, 14–18 good.

The weights of the calves out of the Angus, B x A and B x H cows did not differ significantly from each other but were significantly lower ($P<.01$) than those of the calves out of H x A cows. Calves out of the purebred Angus cows were 4.16 lb. lighter at birth than the average of those produced by the crossbreds.

The adjusted 210-day weights were 498.01 lb. for the S x A, 513.06 lb. for the S x HA, 557.47 lb. for the S x BA and 537.61 lb. for the S x BH calves. The difference between the weights of the calves out of the Angus

TABLE 4. SIGNIFICANCE OF DIFFERENCES BETWEEN MEANS OF BREEDING GROUPS FOR TRAITS STUDIED

	Mean differences and probabilities of chance occurrence				
Breed of dams	Birth weight	210-day weight	Slaughter grade	Carcass grade	Dressing percentage
HA—A	8.10**	15.05	0.32	1.32**	—.46
HA—BA	5.61**	—44.41**	0.49	1.04*	—.19
HA—BH	7.22**	—24.55**	1.33*	1.59**	—1.59**
BH—A	0.88	39.60**	—1.01	—.27	1.13*
BH—BA	—1.61	—19.86*	—.84	—.55	1.40**
A—BA	—2.49	—59.46**	0.17	—.28	0.27

* Significant at .05 level.
** Significant at .01 level.

and H x A dams was not significant. Differences found in all the other comparisons were significant. Calves out of the B x A dams were significantly heavier at 210 days of age than the calves out of the other breeding groups. The calves out of the B x H dams were heavier than those out of Angus or H x A cows. The S x A calves which were the lightest at birth were also the lightest at 210 days of age. The S x HA calves which were heaviest at birth, made slower gains during the suckling period and weighed less than the S x BA and the S x BH at 210 days of age.

The average 210-day weight of the calves out of dams that were sired by Brahman bulls was 34.48 lb. heavier than those out of the British crossbred dams and 49.53 lb. heavier than those out of purebred Angus cows.

There was only one-third grade variation in the average slaughter grade of the calves from the different breeding groups. The calves out of B x H cows graded high good while those from the other groups graded middle good. The only difference that was large enough to be significant was found when the S x BH were compared with the S x HA calves.

Calves out of the H x A cows which had the poorest slaughter grade also produced the lowest grading carcasses. The carcasses from these calves graded low good, which was significantly different from those produced by the other breeding groups. The grades of the carcasses from calves out of Angus, B x A and B x H cows were middle good.

The calves out of B x H cows had the best slaughter and carcass grades

and also the highest dressing percentage. The average dressing percentage of these calves was significantly higher than that found in the other groups. The calves out of Angus, B x A and H x A cows did not differ significantly.

Summary

Purebred Angus and crossbred Brahman x Angus, Hereford x Angus, and Brahman x Hereford cows were bred to a Shorthorn bull. One bull was used for the entire test and all cows were bred to him each year. Birth weights, 210-day weights, slaughter grades, carcass grades and dressing percentages were obtained on 167 calves. The data were adjusted by least squares methods for differences due to year of birth and sex. A steer calf born in 1957 was the basis for the adjustment of each calf's record.

The calves out of Hereford x Angus cows had an average adjusted birth weight of 75.39 lb. and were significantly heavier than those in the other groups. No significant differences were found among the birth weights of the other groups.

The two groups of cows that were sired by the Brahman bulls produced the heaviest calves at 210 days of age. The average weight of the calves out of Brahman x Angus cows was 557.47 lb. as compared to 537.61 lb. for those out of the Brahman x Hereford cows. The weights of these groups were significantly different and both groups were significantly heavier than the calves out of the Hereford x Angus or purebred Angus cows.

The average slaughter grades of the calves varied from middle to high good. Calves out of Hereford x Angus cows were graded lower than those out of the Brahman x Hereford cows. There were no significant differences between the other groups. The carcass grades were significantly lower for the calves out of the Hereford x Angus cows. Differences between the other groups were not significant. The dressing percentages of the calves out of the Brahman x Hereford cows were significantly higher than in the other groups. No other significant differences were found.

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SEASONAL CHANGES IN THE SEMEN OF RAMS

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EACH year in the central valley of California, about 10% of the breeding ewes fail to lamb. In certain years the percentage of "dry ewes" in individual flocks may be higher. Available information indicates that the problem may be environmental in nature, because a high percentage of the nonlambing ewes produce lambs in subsequent years. Because ram fertility may influence breeding efficiency under these conditions, semen was collected over the entire year to determine the seasonal changes in quality occurring under these environmental conditions.

Experimental

In the first experiment, semen was collected at biweekly intervals from three rams (two Suffolk and one Hampshire), using a Marden electroejaculator, from April 1, 1956, to March 31, 1957. In May, two Rambouillet rams were added to the group. In the second experiment semen was collected weekly from four Suffolk rams from October 1, 1957, through September 30, 1958. At each collection, using an artificial vagina and a teaser ewe, an attempt was made to obtain two samples from each ram, but this was not always possible in the spring, because of decreased libido in some rams.

Motility was estimated immediately after collection. Then a slide was prepared for differential staining of live and dead sperm according to the method of Mayer *et al.* (1951), and portions of the sample were deproteinized for determination of fructose and citric acid. Abnormal spermatozoa were counted from the live-dead slides, and concentration of sperm was determined by counting in a hemocytometer. Fructose was determined by the method of Mann (1948), and citric acid by the method of Saffran and Denstedt (1948).

Results

Table 1 shows seasonal variations in the characteristics of semen from the Suffolk and Hampshire rams during 1956–57. These values, obtained on semen collected by the electrical method, reflect the variations found in individual samples. In general, consistent values were obtained for percentage live spermatozoa, and percentage abnormals. On the other hand, values for concentration of spermatozoa, fructose, and citric acid were

quite variable, and motility values tended to vary greatly because they were affected by the concentration of spermatozoa in the sample.

Table 2 shows seasonal variations in the characteristics of semen obtained from the Suffolk rams. Tables 1 and 2 show the average maximum daily temperatures in each month of the experiments.

One Suffolk ram was injected with 25 mg. of testosterone propionate three times weekly from April 23 to June 9, 1958. Fructose concentration

TABLE 1. AVERAGE VALUES OF THE CHARACTERISTICS OF SEMEN COLLECTED FROM RAMS (TWO SUFFOLK AND ONE HAMPSHIRE) FROM APRIL 1, 1956 TO MARCH 31, 1957 USING THE MARDEN EJACULATOR

Month	Conc. sperm X $10^6/\mu l$.	Motility, %	Live, %	Abnormal, %	Fructose, mg./ 100 ml.	Citric acid, mg./ 100 ml.	Average maximum daily temp., ° F.
1956							
Oct.	2.59	57	68	3	450	301	76.6
Nov.	1.53	53	58	4	411	170	68.8
Dec.	1.65	52	52	16	334	106	57.8
1957							
Jan.	1.45	52	54	15	225	...	53.3
Feb.	1.94	54	..	10	90	...	59.0
Mar.	1.93	70	..	9	65	28	64.5
1956							
Apr.	1.66	70	73	12	76	38	71.5
May	1.17	54	54	18	147	68	78.9
June	2.39	90	65	8	109	51	89.2
July	3.18	59	58	9	172	84	92.8
Aug.	0.72	43	52	26	192	...	91.0
Sept.	2.72	69	81	4	255	173	88.9

in the semen was thereby increased about 600%—from 60 mg. per 100 ml. in April to 429 mg. in May. In June, when fructose concentration in the semen of the control rams began to increase, testosterone injections were stopped, and fructose concentration in the injected ram continued to rise, paralleling the rise in the control rams. Other characteristics of the semen were not affected by the injections. Fructose values from this ram for the month of May are not included in table 2.

Another ram received 25 mg. of progesterone three times weekly from April 23 to May 23. None of the observed characteristics of the semen were affected. Fructose concentration, for example, was 188 mg. per 100 ml. in April, and 126 mg. in May. In June it began to rise along with that of the control rams.

One ram was treated with chorionic gonadotropin (Gonamone, courtesy of Fort Dodge Laboratories) between February 25, and March 18, 1959.

TABLE 2. AVERAGE VALUES OF THE CHARACTERISTICS OF THE SEMEN COLLECTED FROM SUFFOLK RAMS FROM OCTOBER 1, 1957 TO SEPTEMBER 30, 1958 USING AN ARTIFICIAL VAGINA

Month	Volume, ml.		Conc. sperm X $10^6/\mu l$.		Motility, %		Live sperm, %		Abnormal, %		Fructose, mg./100 ml.		Citric acid, mg./100 ml.		Av. max. daily temp., ° F.
1957															
Oct.	1.34(28)[a]	.098[b]	3.37(11)	.22	81(29)	1.8	79(15)	1.5	5.5(15)	.043	595(29)	32	75(29)	5.2	71.3
Nov.	1.52(23)	.110	3.32(16)	.18	79(22)	2.3	77(16)	1.4	7.2(16)	.71	524(22)	25	104(22)	6.9	64.4
Dec.	1.40(7)	.170	3.64(4)	.45	82(8)	2.3	..	...	8.5(4)	2.53	496(12)	32	160(12)	25.6	52.5
1958															
Jan.	1.12(12)	.086	3.14(13)	.14	68(14)	3.0	39(5)	4.0	14.6(16)	1.74	387(15)	12	26(16)	9.1	52.6
Feb.	1.04(13)	.121	3.43(9)	.29	72(13)	2.8	62(9)	3.0	15.0(9)	2.53	227(13)	29	58(13)	6.1	60.6
Mar.	1.23(24)	.085	3.36(15)	.14	73(24)	2.0	61(15)	2.1	14.5(15)	1.44	262(24)	57	37(24)	7.1	60.4
Apr.	1.08(41)	.059	3.09(23)	.12	71(41)	1.7	60(19)	2.5	18.1(19)	1.87	199(39)	25	43(39)	2.7	71.9
May	0.89(30)	.053	2.48(19)	.13	79(31)	1.5	61(23)	1.7	20.4(23)	2.59	202(23)	24	54(20)	6.1	82.3
June	1.04(38)	.050	2.39(33)	.14	75(39)	1.5	63(28)	1.9	9.5(28)	1.47	393(31)	32	70(30)	7.3	86.3
July	1.09(23)	.071	2.44(23)	.19	59(24)	3.4	49(20)	1.4	13.1(24)	3.60	477(23)	49	95(23)	24.6	92.5
Aug.	0.96(19)	.044	1.94(19)	.19	35(19)	2.9	25(19)	3.0	31.5(19)	1.50	673(19)	13	44(19)	5.8	97.8
Sept.	0.91(26)	.069	1.83(26)	.13	58(25)	6.2	23(26)	2.1	14.7(26)	1.42	667(26)	16	75(26)	12.7	91.9

[a] Number in parenthesis is the number of observations going into the mean.
[b] Standard error $\pm$ of the mean in the second column of figures under headings.

Injections were given subcutaneously at rates of 250 i.u. daily the first week, 500 i.u. daily the second week, and 1000 i.u. daily the third week. Fructose concentration was unaffected, being 335 mg. per 100 ml. before injection, 349 mg. during injection, and 359 mg. after injection.

Discussion

In the central valley of California both light and temperature appear to affect the characteristics of the semen produced by rams. Seasonal changes closely associated with the annual light cycle occurred in the semen with fructose concentration showing the greatest change.

Glover (1956) reported high concentrations of fructose in the semen from rams during the middle breeding season, followed by a decline. He also found an inverse relationship between the number of spermatozoa and fructose concentration during the breeding season. Except for one Rambouillet, these rams showed a decrease in fructose concentration beginning in December, dropping more rapidly in January, and reaching a low point in April or May. The concentration began to rise in June and reached a maximum in October in the first experiment, and in August in the second. As measured by fructose concentration, ram response to changes in the annual light cycle is more rapid than the response reported for ewes.

Fructose concentration is considered to be a reflection of testosterone secretion (Mann, 1954) and indirectly of gonadotropin secretion. If the fructose secretion is an accurate index of testosterone secretion, these data indicate a definite cyclic secretion of testosterone in the ram. Since testosterone secretion is under the influence of gonadotropin(s) from the pituitary, the data further suggest a cyclic secretion of gonadotropin(s). The failure of chorionic gonadotropin to cause an increase in fructose concentration in the semen may be due to the qualitative characteristics of the material, and this experiment should be repeated with gonadotropins from sheep pituitary.

A simple correlation between total sperm per ejaculate (volume x concentration) and fructose concentration for the months of October through May indicates a relationship between spermatozoa production and testosterone secretion ($r=0.67$, df 7, $p<.05$). Both volume per ejaculate and sperm concentration changed during the year, volume showing the greater change.

One Rambouillet ram showed a different cyclic pattern of fructose secretion in that the concentration was low in this ram when it was high in the other rams. The concentration of fructose in the semen from this ram averaged 491 mg. per 100 ml. in February and March and 44 mg. per 100 ml. in September and October. The other Rambouillet ram showed the same seasonal pattern found in the Suffolk and Hampshire rams. The

difference is not explained by present information and further experiments are needed to determine influence of breed and individuality.

Superimposed on the seasonal effects associated with light, changes associated with high temperature became important during August in the first experiment and during July, August, and September in the second. The data support those of McKenzie and Berliner (1937) and Dutt and Simpson (1957) on the effect of high temperatures on semen. The high temperatures caused a decrease in volume of ejaculate, spermatozoa concentration, motility, per cent of live sperm and normal sperm. On the other hand, temperature had no effect on the fructose concentration or libido of the rams, indicating that the secretion of testosterone was not affected. The correlation between fructose concentration and spermatozoa per ejaculate for the 12-month period was —.07, compared to 0.67 during the period of October through May further indicating the independent effect of temperature.

Hafez *et al.* (1955) reported two peaks of higher-quality semen during the season. They found an increase in volume per ejaculate, increased motility, and increased concentration of spermatozoa in April-May and again in September-October. The quality of semen from these rams showed a minor seasonal improvement in June and July, a major improvement during September, October, and November in the first experiment, and in the second experiment a minor improvement in June and a major one beginning in late September and continuing through October and November. These peaks are probably caused by an interaction between the environmental effects of light and temperature.

Summary

Semen collected from six Suffolk, one Hampshire, and one Rambouillet ram with either an electroejaculator or artificial vagina showed similar seasonal changes in volume of ejaculate, spermatozoa concentration, motility, percentage live spermatozoa, percentage abnormal spermatozoa, and fructose and citric acid concentration. One Rambouillet ram showed a reversed seasonal pattern in fructose concentration. The seasonal changes in the characteristics of the semen were associated with seasonal changes in light and maximum daily temperature.

Injections of testosterone in one ram increased fructose concentration in the semen. Chorionic gonadotropin had no effect on fructose concentration.

The seasonal effects associated with high temperature affected the spermatogenic function of the testis without changing fructose concentration in the semen.

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A COMPARISON OF CERTAIN PHYSICAL AND CHEMICAL CHARACTERISTICS OF EIGHT PORK MUSCLES [1, 2]

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ADJACENT pork muscles frequently exhibit pronounced variation in color and general appearance. This color variation was reported by Scaife (1955) as an anatomical feature of pork muscle yet this color variation is variable between animals. The ultimate pH of the pork musculature has also been implicated in the alteration of the color or general appearance of the chilled product. (Bate-Smith, 1948; Briskey *et al.*, 1958; Lawrie, 1958; Ludvigsen, 1954; Wismer-Pedersen, 1959). Variations in pH within a muscle have been ascribed to bone proximity (Callow, 1939), connective tissue content (Bate-Smith, 1948) and myoglobin distribution (Scaife, 1955). The concentration of myoglobin in the musculature of dark-cutting beef is within the normal range and does not explain the color intensity of this muscle condition (Lawrie, 1958). Briskey *et al.*, (1958) found no significant difference between the myoglobin concentration of light and dark *gluteus medius* pork muscles. The *gluteus medius* and *gluteus accessorius* muscles of two-toned hams were studied further by Briskey *et al.* (1958) and were found to be similar in appearance at the time of death regardless of the severity of the color contrast subsequent to a 24-hour chilling period. These pronounced differences were regarded as a reflection of the degree of decrease in the pH and therefore water-binding capacity of the muscle.

The purposes of this paper are (1) to compare certain chemical and physical properties of eight pork muscles from various locations in the carcass, (2) to show the effects of ham muscle color, or classification, on the characteristics of other pork muscles, and (3) to report the relationships of various characteristics with the water-binding properties of the muscle.

Experimental

The carcasses from 40 Poland China barrows ranging in weight from 190 to 235 lb. were used in this study. As the animals were bled, samples from the *gluteus medius, biceps femoris, rectus femoris* and *gluteus accessorius* ham muscles were removed from the right ham. At the time of slaughter the pH values were determined and the samples were frozen in dry ice for subsequent glycogen analysis. After the carcasses were chilled for a 24-hour period at 34°–38° F., the left hams were removed by cutting

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between the second and third sacrac vertebra, perpendicular to the shank. The exposed ham butt muscles were classified in accordance with the following muscle descriptions:

I. "Pale two-toned" hams ranged from a pale, soft and watery condition to a two-toned, pale appearance. Muscles were definitely lacking in firmness and remained moderately "watery" after cutting.

II. "Grayish-pink" hams were uniform in color and moderately firm in structure.

III. "Dark" hams ranged from a dark two-toned color to a uniform dark color. Muscles were firm in structure and dry in appearance immediately after cutting.

Chilled samples (24-hour) were removed from the *gluteus medius* (ham),

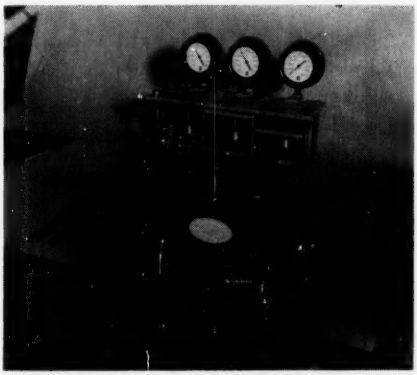

Figure 1. Filter paper moisture absorption apparatus.

gluteus accessorius (ham), *rectus femoris* (ham), *biceps femoris* (ham), *longissimus dorsi* (loin), *pectoralis profundus* (belly), *serratus ventralis* (Boston-butt) and *terres major* (picnic shoulder).

The pH, glycogen, ether extract and total moisture determinations were conducted by the methods previously described (Briskey *et al.*, 1959). The myoglobin values were determined according to the procedure reported by Ginger, Wilson and Schweigert (1954). Approximately 2.56 gm. of KH_2PO_4 and 2.08 gm. of K_2HPO_4 per 10 ml. of solution were added to bring the pH of the supernatant to 6.6 and the phosphate concentration to 3 M. An equal distribution of myoglobin was assumed to exist in the "water phase" of the supernatants and residues in the first extraction. The mg. of myoglobin per gram of tissue were calculated on the basis of this assumption.

Measurements of expressible water were made by modifying the rapid method proposed by Grau and Hamm (1953). The modified apparatus (Fig. 1) consisted of plexiglass plates which were placed between two

¼-inch aluminum sheets. These sheets were connected to a steel frame, hydraulic-jack and pressure gauge similar to the procedure recently reported by Wierbicki and Deatherage (1958). When the sample was prepared for measurement, a filter paper sheet was singularly removed from a humidifier and placed between the plexiglass plates. The sample (0.3 gm.) was immediately placed on the mid-portion of the paper. Four thousand p.s.i. of pressure were applied for a 5-minute period. The muscle and water (juice) areas were subsequently measured with a polar planimeter and the amount of expressible water was recorded as a percentage of the total water by modification of the formula reported by Wierbicki and Deatherage (1958). It was found that the type of paper, treatment of paper, amount of pressure and duration of pressure were important consideration in this study. For these reasons, there were only 44.07 mg. H_2O per square inch of juice area. This is in comparison to the 61.10 mg. of H_2O per square inch reported by Wierbicki and Deatherage (1958) with coarser paper and reduced pressure. The data were analyzed statistically by the analysis of variance and correlation methods outlined by Snedecor (1950).

Results

Table 1 summarizes the comparison of the ultimate pH, expressible H_2O, myoglobin, fat and total H_2O values for eight pork muscles of distinctively different physiological functions and anatomical locations (Briskey *et al.*, 1959).

The pH values at the time of slaughter ranged from 6.1 to 7.1, showed extreme variation between animals, and were not significantly different between muscles. For this reason the muscles are listed in table 1 in descending order of their ultimate (24-hour) pH values. The ultimate (24-hour) pH values ranged from 6.06 for the *gluteus accessorius* to 5.60 for the *longissimus dorsi*. The first values in descending order represent the two dark ham muscles (*gluteus accessorius* and *rectus femoris*), the Boston-butt muscle, (*serratus ventralis*) and the picnic shoulder muscle (*terres major*). The last four pH values represent the two light ham muscles (*gluteus medius* and *biceps femoris*), the *longissimus dorsi* and the belly muscle (*pectoralis profundus*). Both the *longissimus dorsi* and the *gluteus medius* are significantly ($P<0.01$) lower in pH than the first four muscles (1–4), while the *gluteus accessorius* and *rectus femoris* are significantly ($P<0.01$) higher in pH than the last four muscles (5–8).

It can be noted that the four muscles which had the lowest pH values also possessed the greatest percentages of expressible water. Likewise, the muscles (5–8) with the lowest pH values also contained the greatest myoglobin concentrations. The significant differences in the total H_2O concentrations of the various muscles appear, as would be expected, to be approximately in reverse order of the percentage of fat in the sample.

TABLE 1. COMPARISON OF CERTAIN PHYSICAL AND CHEMICAL CHARACTERISTICS OF EIGHT PORK MUSCLES

Muscle	1 Gluteus accessorius	2 Rectus femoris	3 Serratus ventrelis	4 Terres major	5 Biceps femoris	6 Pectoralis profundus	7 Gluteus medius	8 Longissimus dorsi	Significance[c] (P<0.01)
Characteristic									
pH (24 hr.)	6.06	6.01	5.92	5.88	5.83	5.76	5.68	5.60	1 & 2 X 5, 6, 7, 8 3 & 4 & 5 X 7, 8
Exp. H_2O,[a] %	52.98	53.18	50.14	52.37	57 04	53.99	59.07	55.42	1 & 4 X 5, 7 2 X 7 3 X 5, 7, 8 5 X 1, 3, 4
Myoglobin,[b] mg./gm.	8.66	7.48	8.77	6.69	4.64	2.75	2.88	2.17	1 & 3 X 5, 6, 7, 8 2 & 4 X 6, 7, 8 5 X 1, 3
Fat, %	4.75	2.59	8.65	5.15	4.77	9.30	3.95	4.64	1 X 2, 3, 6 2 X 1, 3, 4, 5, 7, 8 3 & 6 X 1, 2, 4, 5, 7, 8
Total H_2O, %	73.15	74.98	71.20	73.67	72.16	68.60	72.21	72.95	1 X 2, 3, 6 2 X 1, 3, 4, 5, 7, 8 3 X 1, 2, 4, 6, 7, 8 6 X 1, 2, 3, 4, 5, 7, 8

[a] Percent expressible H_2O of total H_2O at 24 hr. after slaughter.

[b] Milligrams of myoglobin per gram of tissue (fat-free, dry weight) with the assumption of equal distribution within the water phase of the supernatants and residues of the first extraction.

[c] Example of interpretation of significance (pH values of muscles 1 and 2 are significantly different from the pH values of muscles 5, 6, 7 and 8).

Tables 2 and 3 summarize the effect of ham muscle class (appearance) on the physical and chemical characteristics of the eight muscles. The ham muscles (*gluteus medius, biceps femoris* and *rectus femoris*) showed an increase in pH and a decrease in expressible H_2O and glycogen between the "Ham class I" (Pale-two-toned) and the "Ham class III" (Dark). The pH values and percentages of expressible H_2O showed definite trends but no significant differences for the *gluteus accessorius*. Similarly there

TABLE 2. COMPARISON OF CERTAIN CHARACTERISTICS BASED ON HAM MUSCLE CLASSIFICATION

Muscle	Ham[a] class	pH (24 hr.)	Exp. H_2O[b] (%)	Glycogen[c] (mg./gm.)	Total H_2O (%)	Myoglobin[d] (mg./gm.)
Gluteus medius (Ham)	I	5.45**	63.34*	26.33**	72.12	2.49
	II	5.75**	58.67*	12.04*	72.25	2.54
	III	5.86**	54.40*	6.47*	72.26	3.68
Biceps femoris (Ham)	I	5.66**	60.08**	22.46**	72.02	4.64
	II	5.81**	57.45**	14.33**	72.07	4.62
	III	6.05*	52.58	8.73	72.41	4.66
Rectus femoris (Ham)	I	5.88	56.84	12.42	75.19	7.22
	II	5.90	54.20	10.71	74.49	7.63
	III	6.26*	47.70*	6.18	75.25	7.65
Gluteus accessorius	I	5.98	54.20	12.60	73.07	7.96
(Ham)	II	6.09	52.98	7.08	73.96	8.41
	III	6.11	49.53	3.55*	73.46	9.55

[a] Ham muscle classes reflect differences in color structure and "wateriness". (I—Pale-two-toned; II—Normal—Grayish-pink; III—Two-toned dark to uniform dark).

[b] Expressible H_2O as a percentage of total H_2O determined by the "Filter Paper Moisture Absorption" technique previously described.

[c] Expressed on a fat-free, dry weight basis.

[d] Milligrams of myoglobin per gram of tissue (fat-free, dry weight) with the assumption of equal distribution within the water phase of the supernatants and residues of the first extraction.

* Significantly different, at the 5% level from the underlined observation(s). (Each muscle analyzed separately).

** Significantly different, at the 1% level from the underlined observation(s). (Each muscle analyzed separately).

were no significant differences in the percentages of total water and the concentration of myoglobin in the four ham muscles regardless of the classification of the ham. The pH values and expressible H_2O percentages of the *serratus ventralis* and *longissimus dorsi* (table 3) also varied significantly ($P<0.05$) due to ham "muscle class". The remainder of the data in table 3 for total H_2O percentage and myoglobin concentration showed no significant differences within muscles.

Correlation coefficients showing the relationships between expressible H_2O, muscle class, myoglobin and pH for the eight muscles studied are given in table 4. The correlations between expressible H_2O, pH and muscle class were of the greatest magnitude for the *gluteus medius* and the *biceps femoris*.

Significant correlations between pH and myoglobin also exist for the *gluteus accessorius* and *pectoralis profundus*. A correlation coefficient of

TABLE 3. COMPARISON OF CERTAIN CHARACTERISTICS BASED ON THE APPEARANCE OF THE EXPOSED HAM MUSCLES

Muscle	Ham[a] class	pH (chilled)	Exp. H_2O[b] (%)	Total H_2O (%)	Myoglobin[c] (mg./gm.)
Serratus ventralis	I	5.69*	55.01*	71.60	8.32
(Boston-butt)	II	5.93*	49.53	71.61	8.69
	III	6.15*	45.47	70.36	9.33
Terres major	I	5.79	55.62	74.29	6.45
(Picnic shoulder)	II	5.85	50.95	73.70	7.05
	III	6.00*	50.34	72.99	6.60
Pectoralis profundus	I	5.71	56.23	68.56	2.94
(Belly)	II	5.74	54.40	69.49	2.77
	III	5.86	51.15	67.74	2.56
Longissimus dorsi	I	5.53	59.47*	72.64	2.20
(Loin)	II	5.57	52.78	72.33	2.07
	III	5.91**	53.79	73.91	2.25

[a] Ham muscle classes reflect differences in color, structure and "wateriness". (I—Pale-two-toned; II—Grayish-pink; III—Two-toned dark to uniform dark).

[b] Expressible H_2O as a percentage of total H_2O determined by the "Filter Paper Moisture Absorption" technique previously described.

[c] Milligrams of myoglobin per gram of tissue (fat-free, dry weight) with the assumption of equal distribution within the water phase of the supernatants and residues of the first extraction.

* Significantly different, at the 5% level from the underlined observation(s). (Each muscle analyzed separately).

0.41 between pH and myoglobin has been derived for all eight muscles combined.

The correlations in table 5 point up the relationships between glycogen, pH, muscle class and expressible H_2O for the four ham muscles. These data also show that the characteristics are most highly related in the *gluteus medius* and *biceps femoris* muscles. Significant correlations between pH values for three of the four ham muscles are also shown in table 5.

Discussion

The initial pH values were not reported in this paper since there were no significant differences between muscles. Characteristic differences in

TABLE 4. CORRELATIONS BETWEEN CERTAIN CHEMICAL AND PHYSICAL CHARACTERISTICS OF EIGHT PORK MUSCLES

Characteristics Correlations between:	Gluteus medius	Biceps femoris	Rectus femoris	Gluteus accessorius	Longissimus dorsi	Serratus ventralis	Terres major	Pectoralis profundus
Expressible H_2O (% of total) and,[a]								
Ham muscle class[b]	−.61**	−.51*	−.45*	−.32	−.39*	−.41*	−.30	−.31
pH[c]	−.68**	−.62**	−.39*	−.09	−.38*	−.49*	−.52*	−.18
Muscle pH[c] and,								
Myoglobin (mg./gm.)[d]	+.30	+.17	+.33	+.43*	+.15	+.35	+.23	+.60*
Ham muscle class[b]	+.40*	+.68**	...	...	+.63**	...	...	+.20

[a] Expressible H_2O as a percentage of total H_2O determined by the "Filter Paper Moisture Absorption" technique previously described.
[b] Ham muscle classes: I—Pale-two-toned; II—Grayish-pink; III—Dark.
[c] At 24 hr. after slaughter.
[d] Milligrams of myoglobin per gram of tissue (fat-free, dry weight) with the assumption of equal distribution within the water phase of the supernatants and residues of the first extraction.
* Significantly different, $P<0.05$.
** Significantly different, $P<0.01$.

the ultimate pH values of various beef muscles have been shown by Howard and Lawrie (1957). Similar differences have been shown by Briskey *et al.* (1958) for the *gluteus medius* and *gluteus accessorius* pork ham muscles.

Data presented in table 1 represent eight muscles with various functions i.e., extension, flexion, abduction and retraction (Briskey *et al.*, 1959). Wide ranges exist in ultimate pH values, expressible H_2O percentages and myoglobin concentrations between muscles because they apparently have different functions, sensitivities, work loads and chemical compositions. This has been partially explained by Biorck (1949) who related muscle function and activity to its myoglobin content. In 1955 Scaife also reported

TABLE 5. CORRELATIONS BETWEEN INITIAL GLYCOGEN CONCENTRATION, pH, HAM MUSCLE CLASS, AND EXPRESSIBLE H_2O OF FOUR HAM MUSCLES

Characteristics Correlations between:	Gluteus medius	Biceps femoris	Rectus femoris	Gluteus accessorius
Initial glycogen[a] and,				
pH (24 hr.)[b]	−.65**	−.63**	−.09	−.38*
Ham muscle[c] class	−.44*	−.60**	−.13	−.21
Exp. H_2O[d]	+.53*	+.30	+.28	+.37*
pH (Gluteus medius)	...	+.92**	+.49**	+.23
pH (Biceps femoris)	...	...	+.68**	+.31
pH (Rectus femoris)	...	...	...	+.17

[a] At time of slaughter.
[b] At 24 hr. after slaughter.
[c] Ham muscle classes: I—Pale-two-toned; II—Grayish-pink; III—Dark.
[d] Expressible H_2O as a percentage of total H_2O determined by the "Filter Paper Moisture Absorption" technique previously described.
* Significantly different, $P<0.05$.
** Significantly different, $P<0.01$.

a marked relationship between the myoglobin and pH variations in the *semimembranosus, semitendinosus* and *rectus femoris* pork muscles. The ultimate pH values of muscle tissue have been further implicated by Bate-Smith (1936), Bendall (1951), Callow (1937), Ludvigsen (1954), Briskey *et al.* (1958) and Wismer-Pedersen (1959) to be a significant reflection of the initial glycogen concentration. It has also been suggested by Lawrie (1958) that the attainment of an abnormally low pH value might be related to the extent of breakdown of adenosinetriphosphate.

It is understood that the exact amount of free and bound water can not be determined in muscle tissue. This is an accepted fact since there is no specific dividing line between the two types of water. In addition the lack of knowledge of meat protein components and the water of hydration of these components, under different circumstances, limits available measures to a relative status. For these reasons the amount of relative "free-H_2O" is reported in this paper as "expressible H_2O" as a percentage of the total H_2O. The isoelectric point of meat has been reported by Hamm (1959) to approximate pH 5. It was further reported by Hamm (1955)

and confirmed by Briskey *et al.* (1958) that as the pH approached the isoelectric point there were definite increases in the amount of expressible H_2O. A similar relationship for the eight muscles is shown in table 1. The four muscles which had the lowest pH values also possessed the greatest percentages of expressible H_2O. The reverse was true for the four muscles with the highest pH values.

The myoglobin data (table 1) show major differences between muscles. It is interesting to note that when individual muscles were compared, the four muscles which had the highest pH values also showed the greatest myoglobin concentrations and were the darkest in color. This finding supports the data reported by Scaife (1955) which shows a significant correlation between pH and myoglobin concentration. Myoglobin is reported to function in the maintenance of high oxygen tension between contractions when blood flow is inadequate to sustain the high rate of oxygen utilization by the tissue. Muscles with large myoglobin concentrations, therefore, are concerned with slow movements over long periods of time. (Needham, 1926; Hammond, 1932; Millikan, 1939). The importance of activity in determining the distribution of myoglobin in fowl and horse muscles has been clearly demonstrated by Lawrie (1950, 1953).

It can be noted that the *biceps femoris, gluteus medius* and *longissimus dorsi* have "extending" as a major function and show relatively low quantities of myoglobin when compared with the other muscles in the carcass. This can be explained, in part, by an interpretation of Lawrie's (1950) that these muscles have comparatively low connective tissue in the depth of their fibers and, therefore, may not be subject to major difficulties in oxygen transfer. Another explanation is that the muscles with relatively low myoglobin concentrations are not geared continuously for maximum power output. This postulation is supported by the fact that through the use of regular enforced exercise or some other type of severe training, it is possible to increase the myoglobin concentration in these muscles. Another consideration is the importance of pH in determining the color of the muscle with or without high myoglobin concentrations. Muscles of the same myoglobin content may appear much darker at pH 7 than pH 6.3 (Bate-Smith, 1948). This has been further demonstrated Briskey *et al.* (1958) by administering a single severe exercise treatment which reduced the muscle glycogen concentration, raised the pH and increased the color intensity without any apparent effect on the myoglobin present.

The greatest fat concentration appeared in the Boston-butt muscle (*serratus ventralis*) and the belly muscle (*pectoralis profundus*). The variations in fat (%) and total H_2O (%) do not explain the differences in pH, expressible H_2O and myoglobin. The visual variations in marbling in the muscles studied, were, however, very small.

When these characteristics were categorized and compared on the basis of the appearance of the *gluteus medius* and *gluteus accessorius* ham muscles, several definite patterns were shown. (tables 2 and 3). The *gluteus*

medius and *biceps femoris* showed significant differences between the classes in pH, expressible H_2O and glycogen. Although there were significant differences between the individual muscles in myoglobin concentration there were no significant differences in myoglobin concentrations within the muscles regardless of the color of the exposed end of the ham. This supports the findings by Lawrie (1958) of the normalcy of the myoglobin concentration in dark cutting beef, Bate-Smith (1948), of the effect of pH in darkening the color, and the previous work reported by Briskey *et al.* (1958). Explanations for this phenomenon can be found in the theories of Hamm (1955) and Lawrie (1958). Cytochrome oxidase is presumably the principal enzyme responsible for oxygen uptake in biological tissues and is dependent upon pH. If the ultimate pH of the meat is high the rate of oxygen uptake by cytochrome oxidase rises considerably and contributes to the dark color. Hamm (1955) explains this phenomenon in terms of the isoelectric point of the protein, its effect on the "closed" and "open" structure, and its varying light ray reflectance. Preliminary studies of unpublished work Briskey *et al.* (1959) indicate that the juice released by lowering the pH might effect an extraction of myoglobin from the muscle fibers into the extra-cellular water and make the fibers appear light in color.

Carcasses with hams of I, II or III qualities, however, showed relatively few differences in expressible juice, total H_2O and myoglobin in the *terres major* and *pectoralis profundus* (table 3). A few significant differences in pH and expressible H_2O are shown for the *serratus ventralis* and *longissimus dorsi* (table 3).

The correlations between the characteristics studied (tables 4 and 5) show the highest relationships for the *biceps femoris* and *gluteus medius*. These muscles are relatively high in initial glycogen and low in myoglobin concentration. As a result of these characteristics they possess low ultimate pH values, high expressible H_2O percentages (24 hour) and appear pale in color (24 hour). The low correlations shown for the *gluteus accessorius* and *pectoralis profundus* are very low with the exception of the pH to myoglobin relationships. The correlation of 0.41 between pH and myoglobin when all muscles are considered, supports the significant correlations reported by Scaife (1955). These data should not be interpreted to explain the variation in pH within a muscle. However, myoglobin undoubtedly performs some buffering action in muscles post-mortem (Ludvigsen, 1955). It is possible to attain high ultimate pH values, however, with low myoglobin concentrations. It is further recognized that the myoglobin is present as a result of the functional activity of muscle and not as a result of the high pH. In addition, it is conceivable that the presence of the increased pigment quantity may have an effect on the reduced level of glycogen. The greater pigment quantity may permit increased aerobic and anaerobic metabolism prior to and after slaughter and, therefore, contribute to the development of a high pH. The positive correlations

can not be disputed; however, there is still a lack of data to substantiate the importance of such correlations.

The significant correlations between expressible H_2O and pH are very similar to the correlation (0.62) reported by Judge *et al.* (1958) for water-holding capacity and pH. Hamm (1959) in attempting to evaluate the relative importance of pH to expressible H_2O suggested that about one-third of the change in hydration (post-mortem) could be explained by the decrease in pH. He also postulated that about two-thirds of the decrease in hydration (post-mortem) was attributable to the dephosphorylation of ATP. The negative correlations for these factors of 0.68 and 0.62 for the *gluteus medius* and *biceps femoris,* respectively, although relatively high, do not disprove Hamm's postulation. The significant correlation between the ultimate pH values of the *gluteus medius* and the *biceps femoris* as well as other ham muscles shows the importance of the *gluteus medius* pH in predicting the pH of the other large muscles. This was not true, however, for the *gluteus accessorius*. The understanding of the variations in these characteristics and their relationships to muscle function still require further study.

Summary

Certain chemical and physical characteristics of the *gluteus accessorius* (ham) *gluteus medius* (ham), *biceps femoris* (ham), *rectus femoris* (ham), *longissimus dorsi* (loin), *serratus ventralis* (Boston-butt) *terres major* (picnic shoulder) and *pectoralis profundus* (belly) were compared in this study. Extreme (significant) variations in pH, expressible H_2O, glycogen, myoglobin, fat (%) and total H_2O (%) were exhibited between the various pork muscles. Those muscles which exhibited relatively high ultimate pH values, showed lower initial glycogen accumulations, lower ultimate expressible water quantities and greater myoglobin concentrations. These characteristics were compared with each muscle on the basis of the appearance of the chilled ham; and it was found that the appearance of the *gluteus medius* muscle is an especially good indicator of the water-binding characteristics of the *biceps femoris* and *longissimus dorsi* (two of the largest single muscles in the pork carcass). The total H_2O and myoglobin concentration did not vary significantly within each muscle regardless of the appearance of the chilled ham.

The significant correlations and variations between muscles suggest a moderately strong interrelationship of these characteristics in regulating the appearance and water-binding properties of pork muscles in general.

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EFFECT OF ORGANIC AND INORGANIC SOURCES OF UNIDENTIFIED GROWTH FACTORS ON THE GROWING PIG [1]

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SUBSEQUENT to the elucidation of vitamin B_{12} as the "Animal Protein Factor", a great deal of research had indicated that many crude materials contain factors, as yet unidentified, necessary for maximum growth of chicks, turkey poults, rats, calves and swine. Morrison *et al.* (1955a, 1955b) and Reid *et al.* (1955) have presented evidence indicating that approximately one-half of the response is due to substances inorganic in nature and the other one-half due to organic substances. Scott *et al.* (1955) were unable to demonstrate a growth response with the ash of unidentified growth factor sources and suggested that response to inorganic factors may be due to a balance of inorganic nutrients rather than to an unidentified essential mineral *per se*. Conrad and Beeson (1957) implicated calcium and zinc imbalance as a factor responsible for variable results obtained with unidentified growth factors in swine. O'Dell and Savage (1957) found that zinc produced the response obtained with distillers solubles ash.

The objectives of these four experiments were (1) to evaluate critically various organic and inorganic sources of unidentified growth factors, (2) to characterize these factors further, and (3) to develop a reliable biological assay method for unidentified growth factors in the young pig.

In the four experiments, pigs weaned at approximately three weeks of age and averaging 10 lb. initially were fed a semi-purified diet for experimental periods of 6 to 8 weeks (table 1). All experimental materials replaced equal parts of cerelose and corn starch. Six or eight pigs were fed per experimental treatment. Allottment was made by first dividing the pigs by sex into three or four replicates on the basis of initial weight and subsequently into six or eight lots on the basis of weight within replicates. One barrow and one gilt within each replicate were confined together in 4 ft. x 8 ft. concrete-floored pens bedded with ground corn cobs. Litter number and, whenever possible, previous performance were also used as a basis for allottment. Water which was treated with a zeolite softener and feed were supplied *ad libitum* in glass-lined containers. Environmental temperature was maintained between 60° and 75° F. All pigs were weighed weekly, and the experimental data were subjected to analysis of variance (Snedecor, 1956).

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TABLE 1. COMPOSITION OF SEMI-PURIFIED DIET [a]

Ingredients	Percent
Isolated soybean protein [b]	25.00
Glucose (cerelose)	30.97
Corn starch	30.97
Corn oil (Mazola)	5.00
Celluflour	3.00
DL-Methionine	0.25
Mineral mixture [c]	4.00
Trace mineral mixture [d, e]	+
Vitamin mixture [f]	+
Antibiotic [g]	+

[a] Composition by chemical analysis: protein, 20.2%; moisture, 8.0%; ether extract, 5.0%; fiber, 2.2%; calcium, 0.68%; phosphorus, 0.58%; zinc, 16 p.p.m. in experiment I and 69 p.p.m. in experiments II, III and IV.

[b] ADM Assay Protein C-1 (formerly Drackett) manufactured by Archer-Daniels-Midland Co., 2795 Sharon Road, Cincinnati, Ohio.

[c] Mineral mixture supplied the following percent of the ration: iodized NaCl, 0.5; $CaHPO_4$, 2.0; $CaCO_3$, 0.5; KH_2PO_4, 0.5; KCl, 0.5.

[d] Trace mineral mixture used in experiment 1 supplied in grams per 100 lb. of ration: $MgSO_4 \cdot 3H_2O$, 100; $Fe_4(P_2O_7)_3 \cdot 9H_2O$, 40; $MnCl_2 \cdot 4H_2O$, 6; $CuSO_4 \cdot 5H_2O$, 2; CaF_2, 1; $CoSO_4 \cdot 7H_2O$, 0.1.

[e] Trace mineral mixture used in experiments 2, 3 and 4 supplied in grams per 100 lb. of ration: $MgCO_3$, 69.9; $Fe_4(P_2O_7)_3 \cdot 9H_2O$, 25; $MnSO_4 \cdot H_2O$, 7.9; $CuSO_4 \cdot 5H_2O$, 1.2; CaF_2, 1.0; $CoCO_3$, 0.04; ZnO, 3.0.

[f] Vitamins added in mg. per lb. of ration: thiamine HCl, 3.0; riboflavin, 4.0; niacin, 15.0; calcium pantothenate, 10.0; pyridoxine HCl, 1.5; choline chloride, 600; PABA, 4.0; biotin, 0.1; inositol, 50; folic acid, 2.0; ascorbic acid, 50; mixed tocopherols, 15.0; 2-methyl-1,4-naphthoquinone, 1.0. Other vitamins added were: vitamin B_{12}, 20 mcg./lb.; vitamin A acetate, 2,000 I.U./lb.; vitamin D_2, 200 I.U./lb.; vitamin D_3, 200 I.U./lb.

[g] Chlortetracycline HCl was added to supply 25 mg./lb.

Experimental Procedure

Experiment I. Forty-eight Duroc pigs three weeks of age and averaging 10.5 lb. were divided into eight treatments of six pigs each. The trace mineral mixture contained no supplemental zinc which reduced the zinc content of the basal diet to 16 p.p.m., presumably supplied by the isolated soybean protein. The diet contained 0.68% calcium. These levels were used in order to determine if part or all of the unidentified growth factor response was due to the zinc supplied by the crude products used as growth factor sources.

The experimental treatments were as follows: Lot 1—Isolated soy protein basal; Lot 2—Basal+50 p.p.m. elemental zinc; Lot 3—Basal+1 p.p.m. elemental selenium; Lot 4—Basal+5% brewers dried yeast (BDY); Lot 5—Basal+ash of BDY; Lot 6—Basal+5% distillers dried solubles (DDS); Lot 7—Basal+ash of DDS; and, Lot 8—Basal+a reconstituted ash of DDS.

A two-step ashing procedure was used. The crude product was preashed in a stainless steel pan over an open flame until the product had ignited. This residue was then placed in stainless steel pans in an electric muffle at 525° C. for 14 hours for final ashing. The reconstituted ash was based on the spectrographic analysis reported by Couch *et al.* (1955).

The trial was terminated on the 49th day of the experiment owing to severe outbreaks of parakeratosis in several of the experimental lots. The more severe cases of parakeratosis were reallotted and subjected to the following treatments in an attempt to correct this condition: 3 p.p.m. selenium, 3 p.p.m. molybdenum, 50 p.p.m. cadmium, 68 mg. arsanilic acid per lb. of diet, 1% citric acid, or lowering the iron and copper levels from 48 and 4.9 to 15 and 1.5 mg. per lb. of diet, respectively.

Experiment II. The results of experiment 1 indicated zinc was a dietary essential for the growing pig and that the unidentified growth factor response was not due to elemental zinc. Subsequent experimental rations contained 53 p.p.m. supplemental zinc.

Forty-eight Duroc pigs three weeks of age and averaging 11.4 lb. initially were divided into eight treatments of six pigs each. The experimental period was for 56 days. The experimental treatments were as follows: Lot 1—Isolated soy protein basal, Lot 2—Basal+5% DDS, Lot 3—Basal+ash of DDS, Lot 4—Basal+a reconstituted ash of DDS, Lot 5—Basal+5% BDY, Lot 6—Basal+ash of BDY, Lot 7—Basal+3 p.p.m. selenium, and Lot 8—Basal+24 p.p.m. strontium.

The pre-ashing technique was modified from experiment 1. The crude product was pre-ashed in stainless steel pans on a hot plate under a hood for 12 hours. This was then final-ashed as previously discussed. The reconstituted ash was the same as was used in experiment 1.

Experiment III. In experiments 1 and 2 distillers dried solubles appeared to be one of the more potent sources of unidentified growth factors for the pig. Therefore, experiment 3 was designed to study further DDS and various fractions of it. Forty-four Duroc pigs, three weeks of age, were fed the dry semipurified basal diet for 13 days in an attempt to deplete body stores of unidentified growth factors. Performance during this period was also used as another criterion for allotting the pigs into the various experimental treatments. The fastest and slowest gainers were eliminated in an attempt to increase animal uniformity. At the end of the depletion period, 40 of the pigs, averaging 13 lb., were divided into five lots of eight pigs each. The experimental period was for 42 days. The experimental treatments were as follows: Lot 1—Isolated soy protein basal, Lot 2—Basal+5% DDS, Lot 3—Basal+the ash of DDS, Lot 4—Basal+a concentrated methanol extract of DDS, and Lot 5—Basal+the methanol insoluble fraction of DDS.

The ashing procedure was the same as that used in experiment 2. Methanol extraction was accomplished by refluxing 113.5 gm. of DDS in 500 ml. of methanol for one hour in a steam bath. Four of these samples were filtered while still warm through No. 1 Whatman filter paper in a Buchner funnel set in a vacuum flask. The residue from the four samples was washed with a liter of methanol, and the filtrate and washings were combined and concentrated to a small volume under reduced pressure in a vacuum flask partially immersed in a water bath at 55° C. The concen-

trates from 4 lb. of DDS were combined and 1 liter of distilled water was added. The mixture was then reduced to a volume of 1 liter by vacuum distillation. Therefore, 250 ml. of the concentrated extract was equivalent to the extract from 1 lb. of DDS. The concentrate was premixed on the isolated soy protein of the experimental diet. The methanol insoluble residue was dried in an oven at 90° C; 0.65 lb. of the residue was equivalent to 1 lb. of DDS.

Experiment IV. Further fractionation of the factor(s) in DDS was attempted in this experiment. Forty-two, three-week-old Duroc pigs were fed the basal diet for a 14-day depletion period. At the end of the period, 36 of the pigs were divided into six lots of six pigs each averaging 16 lb. initially. The experimental period was for 42 days.

The experimental treatments were as follows: Lot 1—Isolated soy protein basal, Lot 2—Basal+5% DDS, Lot 3—Basal+a concentrated methanol extract of DDS, Lot 4—Basal+the methanol insoluble fraction of DDS, Lot 5—Basal+a chloroform soluble fraction of the methanol extract of DDS, and Lot 6—Basal+a chloroform insoluble fraction of the methanol extract of DDS.

The methanol extraction procedure was the same as discussed in experiment 3. The filtrate and washings from 1 lb. of DDS (3 liters) were combined and concentrated to 125 ml. under vacuum in a steam bath. This left a dark viscous liquid which was premixed on the isolated soy protein of the experimental diet. For chloroform extraction, DDS was extracted with methanol and the filtrate and washings from 4 lb. of DDS were concentrated to 400 ml. under vacuum in a steam bath. This was diluted with 600 ml. of deionized water and placed in a separatory funnel. One liter of chloroform was added and the contents shaken vigorously for 7 minutes. After reaching equilibrium the heavier chloroform fraction was withdrawn, and the aqueous fraction was washed twice more in the same manner. The chloroform fractions were combined and the chloroform removed under vacuum in a warm water bath. The aqueous phase was concentrated in the same manner. These fractions were premixed on the soy protein of the experimental diet.

Results

Experiment I. Fifty p.p.m. supplementary zinc significantly increased average daily gains over all other experimental treatments (table 2) and completely prevented parakeratosis. The ash of BDY significantly ($P<0.01$) increased average daily gains over the control lot; however, the growth rate was significantly ($P<0.05$) slower than that obtained with 50 p.p.m. supplemental zinc. The ash of BDY also partially prevented the parakeratotic syndrome (table 3). Selenium, BDY, DDS, the ash of DDS or a reconstituted ash of DDS gave slight but insignificant increases in average daily gains as compared to the control lot. These treatments gave

TABLE 2. RESULTS OF EXPERIMENT I. THE EFFECT OF VARIOUS ORGANIC AND INORGANIC SOURCES OF UNIDENTIFIED GROWTH FACTORS ON A LOW-CALCIUM, LOW-ZINC DIET (SIX PIGS PER LOT FED FOR 49 DAYS)

Lot no.	Treatment	Av. initial wt.	Av. final wt.	Av.[a] daily gain	Av. daily feed	Feed per lb. gain
		lb.	lb.	lb.	lb.	lb.
1	Soy protein basal[b]	10.6	20.0	0.19	0.93	4.82
2	Basal+zinc (50 ppm)[c]	11.0	54.2	0.88**	1.86	2.12
3	Basal+selenium (1 ppm)[d]	10.8	28.6	0.36	1.16	3.18
4	Basal+5% BDY[e]	10.6	25.2	0.30	1.19	3.99
5	Basal+ash BDY	10.6	38.7	0.57**	1.45	2.53
6	Basal+5% DDS[f]	10.6	25.1	0.30	1.02	3.44
7	Basal+ash DDS	10.5	23.0	0.26	1.45	5.69
8	Basal+reconstituted ash DDS	10.6	29.3	0.38	1.41	3.69

** Significant at the 1% level from the basal lot.
[a] L.S.D. at $P<0.05=0.25$; and $P<0.01=0.33$ lb.
[b] Basal ration contained 0.68% calcium and 16 p.p.m. zinc.
[c] Added as zinc oxide.
[d] Added as sodium selenite.
[e] BDY=brewers dried yeast.
[f] DDS=distillers dried solubles.

no protection from parakeratosis. The basal diet was inadequate for normal growth and a high incidence of parakeratosis resulted. Correctional treatments of 3 p.p.m. selenium, 3 p.p.m. molybdenum, 50 p.p.m. cadmium, 68 mg. arsanilic acid per lb. of diet, 1% citric acid, or lowering the iron and copper content of the diet were without effect in alleviating the parakeratotic syndrome. However, 50 p.p.m. supplemental zinc produced dramatic growth and behavioral responses in parakeratotic pigs.

Experiment II. Five percent DDS increased gains 14% and improved feed efficiency 12% (table 4). The increase in gain approached significance at the 5% level. None of the other experimental treatments increased

TABLE 3. INCIDENCE OF PARAKERATOSIS IN EXPERIMENT I[a]

Severity of parakeratosis[b]	Lot 1 Basal	Lot 2 50 ppm zinc	Lot 3 1 ppm Se	Lot 4 5% BDY	Lot 5 ash BDY	Lot 6 5% DDS	Lot 7 ash DDS	Lot 8 reconst. ash DDS
	no.	no.	no.	no.	no.	no.	no.	no.
1	2	0	2	2	1	1	0	1
2	1	0	1	2	1	1	0	0
3	1	0	0	1	0	1	5	2
4	1	0	1	1	0	2	1	1
Total cases	5	0	4	6	2	5	6	4

[a] Incidence at time of termination of the experiment.
[b] Severity of parakeratosis as follows: 1=first indication of parakeratotic lesions on the belly; 2=belly moderately covered with lesions; 3=belly covered with lesions and extending to backs of legs; 4=lesions very severe on belly, incrustations on backs of legs and extending up to dorsal region of body, extremely moribund.

TABLE 4. RESULTS OF EXPERIMENT II. THE EFFECT OF VARIOUS ORGANIC AND INORGANIC SOURCES OF UNIDENTIFIED GROWTH FACTORS ON A LOW-CALCIUM, HIGH-ZINC DIET (SIX PIGS PER LOT FED FOR 56 DAYS)

Lot no.	Treatment	Av. initial wt.	Av. final wt.	Av.[a] daily gain	Av. daily feed	Feed per lb. gain
		lb.	lb.	lb.	lb.	lb.
1	Soy protein basal[b]	11.4	67.2	1.00	2.31	2.32
2	Basal+5% DDS[c]	11.3	75.0	1.14	2.32	2.04
3	Basal+ash DDS	11.4	63.5	0.93	1.94	2.08
4	Basal+reconstituted ash DDS	11.4	61.5	0.89	2.05	2.29
5	Basal+BDY[d]	11.4	66.7	0.99	2.07	2.10
6	Basal+ash BDY	11.4	69.1	1.03	2.25	2.18
7	Basal+selenium (3 ppm)[e]	11.7	61.4	0.89	1.98	2.23
8	Basal+strontium (24 ppm)[f]	11.4	63.0	0.92	2.03	2.20

[a] L.S.D. at $P<0.05=0.145$ lb.
[b] Basal ration contained 0.68% calcium and 69 p.p.m. zinc.
[c] DDS=distillers dried solubles.
[d] BDY=brewers dried yeast.
[e] Added as sodium selenite.
[f] Added as strontium chloride.

average daily gains; however, all experimental treatments resulted in an improvement in feed efficiency.

Leg abnormalities resembling rickets occurred in this experiment. All lots showed some leg abnormalities; however, 5% DDS gave an apparent reduction in the incidence of this condition. Slight improvement was noted when the ash of DDS or 5% BDY were fed. The heavier pigs were more severely affected, and certain litters showed a tendency for more crooked legs.

Experiment III. All experimental treatments increased rates of gain (table 5). Five percent DDS and the methanol insoluble fractions of DDS

TABLE 5. RESULTS OF EXPERIMENT III. THE EFFECT OF VARIOUS FRACTIONS OF DISTILLERS DRIED SOLUBLES (EIGHT PIGS PER LOT FED FOR 42 DAYS)

Lot no.	Treatment[b]	Av. initial wt.	Av. final wt.	Av.[a] daily gain	Av. daily feed	Feed per lb. gain
		lb.	lb.	lb.	lb.	lb.
1	Soy protein basal	13.0	56.8	1.04	2.47	2.37
2	Basal+5% DDS[c]	13.0	64.1	1.22*	2.79	2.29
3	Basal+ash DDS	13.0	60.6	1.13	2.58	2.28
4	Basal+CH_3OH extract of DDS	13.0	62.5	1.18	2.64	2.24
5	Basal+CH_3OH insol. fraction DDS	12.9	65.1	1.24*	2.94	2.37

* Significant at the 5% level from the soy protein basal lot.
[a] L.S.D. at $P<0.05=0.16$; $P<0.01=0.22$ lb.
[b] All pigs were fed the isolated soy protein basal diet for a two-week depletion period prior to being placed on the experimental treatments.
[c] DDS=distillers dried solubles.

increased average daily gains 17.3% and 19.2%, respectively. These differences were significant at the 5% level. The methanol extract of DDS increased gains 13.5% which approached significance ($P<0.05$). The ash of DDS increased gains 8.6% or approximately one-half the response obtained with the crude product. Leg abnormalities also occurred, and 5% DDS partially alleviated this condition. The other experimental treatments had no beneficial effect. The leg abnormalities appeared to be more closely correlated with the litter from which the pigs originated than with the experimental treatments involved.

Experiment IV. Separate additions of 5% DDS, a methanol extract of DDS, the methanol insoluble fraction, a chloroform extract of the methanol extract or the chloroform insoluble fraction of the methanol

TABLE 6. RESULTS OF EXPERIMENT IV. THE EFFECT OF SOLVENT EXTRACTS OF DISTILLERS DRIED SOLUBLES (SIX PIGS PER LOT FED FOR 42 DAYS)

Lot no.	Treatment[a]	Av. initial wt.	Av. final wt.	Av. daily gain	Av. daily feed	Feed per lb. gain
		lb.	lb.	lb.	lb.	lb.
1	Isolated soybean protein basal	16.1	69.3	1.27	2.80	2.21
2	Basal+5% DDS[b]	16.0	72.0	1.33	3.07	2.30
3	Basal+CH_3OH extract of DDS	16.0	71.8	1.33	2.83	2.13
4	Basal+CH_3OH insol. fraction DDS	15.6	71.6	1.33	3.09	2.32
5	Basal+$CHCl_3$ sol. fraction of CH_3OH extract of DDS	16.4	71.3	1.31	2.68	2.05
6	Basal+$CHCl_3$ insol. fraction of CH_3OH extract of DDS	16.0	71.4	1.32	2.77	2.10

[a] All pigs were fed the isolated soybean protein basal diet for a two-week depletion period prior to being placed on experimental treatments.
[b] DDS=distillers dried solubles.

extract increased average daily gains 3.1 to 4.7% over the control lot (table 6). None of these differences were significant. Feed efficiency was not consistently altered. Five percent DDS increased gains 10.5 to 11.0% during the first 3 weeks of the experiment, but the response progressively diminished the last 3 weeks. Similar results were noted with the other experimental treatments.

Discussion

In experiment 1 a low-zinc (16 p.p.m.) low-calcium (0.68%) diet proved to be inadequate for normal growth; and, a parakeratotic syndrome developed. Conrad and Beeson (1957) had reported a similar diet containing 28 p.p.m. zinc to be adequate for normal growth. Tucker and Salmon (1955) reported parakeratosis was due to a zinc deficiency and that excessive levels of calcium or phosphorus increased the incidence. The

basal used in this experiment did not contain excessive levels of calcium or phosphorus, and the zinc requirement was unknown at this time. Whiting and Bezeau (1958) reported high levels of vitamin D (800 I.U./lb.) decreased zinc absorption and retention in diets low in zinc. The basal used in this experiment contained 400 I.U. of vitamin D per pound of diet. This level of vitamin D may have decreased zinc absorption, but unpublished data from Purdue University has indicated that the source of protein is a major factor affecting zinc absorption. Fifty p.p.m. zinc completely prevented parakeratosis. Supplementing the basal diet with DDS, the ash of DDS, a reconstituted ash of DDS or 1 p.p.m. selenium gave slight but insignificant increases in growth and no protection from parakeratosis. The ash of BDY significantly ($P<0.01$) increased gains over the control lot and partially alleviated parakeratosis. This appears inexplicable on the basis of the zinc contributed by the BDY ash since the ash of DDS contained 3 p.p.m. zinc as compared to only 2 p.p.m. for BDY. Hoefer *et al.* (1958) has recently shown iron and copper may be involved in this syndrome; however, a spectrographic analysis of the ashes of DDS and BDY revealed little difference in their iron and copper content. The results of this experiment are in contrast to the results of Conrad and Beeson (1957) in which DDS gave complete protection and BDY only partial protection from parakeratosis. Robertson and Barnhart (1958) found DDS partially prevented parakeratosis on a high calcium diet. The parakeratotic syndrome appears to be associated with factors other than zinc.

A basal diet containing 0.68% calcium and 69 p.p.m. zinc produced excellent gains and feed efficiency in experiments 2, 3 and 4. Five percent DDS markedly increased gains in experiments 2 and 3, indicating DDS is a potent source of growth factors for the pig. However, in experiment 4 the magnitude of the response to DDS was considerably less than that observed in experiments 2 and 3. The reason for these differences is not apparent. Many variables have been known to affect the growth factor response which may in part account for these discrepancies. Pigs used in experiments 2 and 3 were from dams fed practical gestation rations in drylot composed of corn, soybean oil meal, meat scraps and dehydrated alfalfa meal. The pigs used in experiment 4 were from dams fed practical gestation rations while grazing good alfalfa-ladino pasture. Scott (1957) reported fresh forage juice was a potent source of the factor found in fermentation dried solubles. Work by Robblee *et al.* (1948) and Patterson and McGinnis (1954) has shown high levels of unidentified growth factor sources in the maternal diet reduced the response of progeny of these dams to unidentified growth factors. Also, the pigs used in experiment 4 were at a slightly older age and heavier weight than in the previous experiments. Johnson (1952) and Fry *et al.* (1958) found the response to growth factors decreased as the age of the animal increased. This was attributed to increased feed consumption at older ages meeting the requirements for

growth factors from the factors contained in natural dietary ingredients. Scott *et al.* (1954) presented evidence indicating isolated soybean protein contains unidentified growth factors. Therefore, it is quite possible the pigs in experiment 4 were meeting their requirements from the factors in the isolated soy protein. Another factor of major importance was the source of DDS used. In experiments 2 and 3 the same sample of DDS was used. However, this supply was exhausted and another sample was obtained for experiment 4. Atkinson *et al.* (1953) observed different samples of DDS varied in growth factor potency. The potency of the two samples used in this study may have been markedly different.

A methanol extract of DDS improved feed efficiency and daily gains in experiments 3 and 4; however, the magnitude of the response was somewhat less in the latter experiment. Austin and Boruff (1949) found that a methanol extract of DDS effectively removed a rat growth factor identified as vitamin B_{13}. Cunha *et al.* (1950) reported vitamin B_{13} stimulated gains of growing pigs. Nelson (1958) recently found methanol extraction of DDS did not completely remove all of the factors in DDS, and the factor extracted was different from vitamin B_{13}. The results of experiments 3 and 4 agree with this work. The methanol insoluble fractions gave responses comparable to the crude product. This indicates the extraction procedure failed to remove all of the factor or that DDS contains more than one growth factor, one soluble and one insoluble in methanol. The methanol soluble and insoluble fractions produced total responses approximately twice that obtained with the crude DDS. This would tend to indicate possible liberation of a bound form of the growth factors in DDS by methanol extraction. This is in agreement with work by Couch *et al.* (1955).

The results of the chloroform partitioning of the methanol extract are inconclusive. Although both fractions increased growth slightly, these differences were not significant. In view of the poor results obtained in experiment 4, no conclusions can be drawn. Austin and Boruff (1949) reported chloroform could be used for direct extraction of vitamin B_{13} from DDS. However, Couch *et al.* (1955) were unable to extract the chick factor in DDS with chloroform, and more recently Nelson (1958) found treatment of active fractions of DDS with chloroform destroyed the activity for rats.

Variable responses were obtained with the ash of DDS. No response was obtained in experiment 2. Briggs (1956) obtained similar results and suggested much of the work showing a response to ash was done with diets using inadequate mineral mixtures. However, in experiment 3 the ash response was approximately one-half that obtained with crude DDS. This is in agreement with work by Camp *et al.* (1956), Morrison *et al.* (1955a and 1955b) and Reid *et al.* (1955).

The results obtained with the reconstituted ash of DDS are inconclusive because the results were unavoidably confounded in both experiments in which this treatment was tested. Growth rate was not affected by additions of BDY or the ash of BDY when an adequate diet was fed. Conrad and

Beeson (1957) reported a growth response in pigs with BDY; however, the diet used contained only 28 p.p.m. zinc. Gard *et al.* (1955) were unable to obtain any clear-cut evidence that brewers yeast contained growth factors for the pig.

Although Schwarz and Foltz (1957) and Nesheim and Scott (1958a) have shown selenium is an essential trace element for the rat and chick, no response was obtained in the growing pig under the conditions of this experiment. Nesheim and Scott (1958a) reported soybean oil meal contained 0.6 p.p.m. selenium which may have been adequate to meet the pigs requirement in these experiments.

Strontium did not appear to be essential for the pig under the conditions of this experiment. Rygh (1949) found strontium to be indispensible for the rat and guinea pig, but confirmation of this work in other species is lacking at this time.

Leg abnormalities in experiments 2 and 3 appeared to be improved by DDS and slightly improved by the ash of DDS and BDY. Supplee *et al.* (1956) and Hixson and Rosner (1954) reported an improvement in the hock condition in chicks with DDS and BDY, respectively. Little abnormalities occurred in experiment 4; and in view of the possible body stores of growth factors in this experiment, the lowered incidence of leg abnormalities may have been due to these unidentified factors. However, examination of all the data from litter mates in these experiments and pigs under comparable conditions in another study, it was found that maternal origin influenced the condition as much as experimental treatments. A lowered incidence was also noted when 3 p.p.m. selenium was fed. Scott (1951) reported the enlarged hock condition was the counterpart of exudative diathesis and encephalomalacia in chicks. Since Nesheim and Scott (1958a) have shown exudative diathesis is alleviated by selenium, there may be a possible interrelationship between the selenium treatment and the lowered incidence of leg abnormalities. However, the pigs receiving selenium also reached the lightest final weight in experiment 2. A definite trend for the heavier pigs to have more leg abnormalities was noted; therefore, the lowered incidence may not have been of dietary origin.

Comparison of comparable treatments between experiments 2 and 3 indicate the growth factor response was enhanced by a two-week depletion period. This is in agreement with work by Morrison *et al.* (1955b) and Barnett and Bird (1956) with chicks. The lack of response in experiment 4 may have been due to larger body stores; and, thus, the depletion period may not have been of a long enough duration.

Summary

A corn starch-cerelose-isolated soy protein diet containing 0.68% calcium and 16 p.p.m. zinc was inadequate for normal growth, and a high incidence of parakeratosis developed. Fifty p.p.m. supplemental zinc gave normal

growth and completely prevented parakeratosis. The ash of brewers yeast gave partial protection from parakeratosis. This was not attributed to its zinc content. Distillers solubles, the ash or a reconstituted ash of distillers solubles, brewers yeast or 1 p.p.m. selenium were without effect in a low-zinc diet. Zinc did not appear to be the mineral factor responsible for the growth factor response.

Three experiments indicated distillers solubles was a potent source of unidentified growth factors for the young pig fed a semi-purified diet containing optimum amounts of all of the known dietary requirements. Fractionation studies indicated the factor in distillers solubles was partially soluble in methanol or that there was more than one factor present. Methanol extraction possibly liberated a bound form of the unidentified growth factor.

Slight but inconclusive responses were obtained with chloroform soluble and insoluble fractions of the methanol extract of distillers solubles.

Distillers solubles ash increased feed efficiency in two experiments and gave a growth response in one experiment and no response in a second.

Brewers yeast, the ash of brewers yeast, a reconstituted ash of distillers solubles, 3 p.p.m. selenium or 24 p.p.m. strontium improved feed efficiency but had no effect on growth rate when a nutritionally adequate diet was fed.

A two-week depletion period enhanced the pigs response to unidentified growth factors.

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SOME CAUSES OF VARIATION IN POST-PARTUM REPRODUCTIVE ACTIVITY IN HEREFORD COWS [1]

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In general a positive association has been observed between the length of the service period and conception rate at first service. Wiltbank (1955) found a significant negative correlation between the interval from calving to first heat and the interval from breeding to conception when breeding was practiced at first heat. Buch *et al.* (1959) have shown a significant positive association between prolonged "out-of-breeding condition" of the uterus and number of infertile services after the uterus had returned to breeding condition. A significant positive correlation between intervals to involution and to first post-partum heat was shown by Buch *et al.* (1955). Many workers have estimated heritability values both for the post-partum intervals and for fertility to be very low. Olds and Seath (1953), however, reported a heritability of 0.32 for number of days to first heat in dairy cattle. Wiltbank (1955) found no significant differences between Angus and Shorthorn cows in interval to involution or service period length. Buch *et al.* (1955) reported an effect of parity on involution rate but not on interval to first estrus.

The associations between the various post-partum intervals, their effect on conception rate, and some of the sources of variation in these intervals have been studied in a group of Hereford twins.

Materials and Methods

The data studied were taken from the reproductive records of an experimental herd of Hereford twins at the University of Wisconsin. Records from a total of 13 pairs of twins (9 fraternal and 4 identical) with 61 service periods (intervals from calving to first service) were studied. The number of service periods per cow ranged from 1 to 3. Not all of the service periods nor all of the cows were used in all parts of the study.

The animals were fed individually but received the same rations of grain, hay and silage, and ran together in a barn and paddock. The cows were checked for heat each day and all were bred at first estrus after calving. Only one bull was used during the period of the experiment.

Unadjusted intervals from calving to involution of the uterus, first ovulation, and first estrus were tested for differences between service periods, twin pairs, and cows within twin pairs by analysis of variance.

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Only the first two service periods from each of 24 animals (8 fraternal pairs and 4 identical pairs) were included in this analysis.

The intervals were adjusted for the effects of service period number, and, by using all 61 service periods from the 26 cows (9 fraternal pairs and 4 identical pairs), comparisons were made between the variation within fraternal pairs and within identical pairs of twins to test for genetic effects. Each interval was adjusted to a first service period basis, using the differences between the averages of first service period intervals and the averages of the second and third service period intervals for the respective adjustment factors. Only first service period intervals of cows having second and third service periods were used in calculating adjustment factors for second and third service period intervals, respectively.

Sixty unadjusted service periods from 26 cows were used to study the fertility of cows first bred before and after uterine involution and at various interval lengths after calving.

Correlations between the intervals to involution and first heat and between each of these and conception rate at first post-partum service and the corresponding standard partial regressions were calculated. The first and second service periods of each cow from eight fraternal and four identical twin pairs were included in these calculations.

The times of uterine involution and first ovulation were determined by weekly rectal palpations which were begun 15 to 22 days after parturition. Pregnancies were diagnosed by rectal palpations at 35 to 41 days post breeding. The terms "conception" and "settle" as used in this study refer to pregnancies carried over 240 days.

Results and Discussion

The average unadjusted intervals from calving to involution of the uterus, first ovulation, and first estrus were 43.7, 38.4 and 58.6 days, respectively. Conception at first post-partum service occurred in 71.4% of the service periods. Variance between service periods, twin pairs, and cows within twin pairs for the different kinds of post-partum intervals was analyzed using only cows with two service periods and including only the first and second service periods on each cow. The difference between first and second service periods was significant only for length of the interval to involution which averaged 11 days shorter in the first than in the second service period. Although successive pregnancies and parturitions or the associated increase in age tend to decrease the involution rate, post-partum ovarian activity itself does not appear to be affected by parity. The length of none of the intervals varied significantly between twin pairs or between cows within pairs. Also the interaction between service periods and twin pairs was non-significant.

Genetic effects on variation in the post-partum intervals were studied by comparing the variances within identical twin pairs to that within

fraternal pairs (table 1). All intervals were adjusted to a first service period basis for this comparison. Variation was greater between fraternal twins than between identical twins for all three intervals but the difference was significant only for time to involution ($P<0.01$). These results, therefore, fail to show a "real" effect of genetics on time of resumption of ovarian activity after calving, but rate of uterine involution may be genetically influenced.

Fertility within the first 60 days after calving was only slightly higher in cows with involuted than in those with non-involuted uteri. Among the cows with involuted uteri, however, the conception rate tended to improve with length of service period. All of the 19 cows bred before involution of the uterus were bred within 60 days after calving and 52.6% of them conceived at first service. Eighteen cows with involuted uteri were bred

TABLE 1. AVERAGES AND VARIANCES OF POST-PARTUM INTERVALS ADJUSTED TO FIRST SERVICE PERIOD

			Fraternal		Identical	
Interval to:	No. of service periods	Average length (days)	DF	Variance within pairs	DF	Variance within pairs
Involution	61	43.4	9	202	4	11
First ovulation	60	37.0	9	375	4	256
First estrus	60	56.0	9	779	4	354

within 60 days and 55.6% settled, and 23 involuted cows were first bred later than 60 days and 65.2% conceived. These results are similar to those of Wiltbank (1955) in which 33.3% of the cows bred before uterine involution and within 60 days after calving conceived, whereas 46.7% of those which were involuted when bred before 60 days settled. He also found that 65.2% of those first bred after uterine involution and later than 60 days conceived.

Correlations between intervals to involution and to first estrus and between each of these and conception rate at first service were calculated between cows within both identical and fraternal twin pairs and between service periods within cows. Only the correlation between interval to first estrus and conception rate, calculated between service periods within cows, was significant ($r=0.40$, $P<0.05$). The corresponding standard partial regression was highly significant ($b'=0.40$). These results suggest that involution rate, as determined by manual palpation, does not influence conception rate either directly or indirectly through an association with interval to first heat, whereas an increase in time to first estrus causes an increase in conception rate. Since first service was at first estrus, a positive association between post-partum interval to first service and fertility was also shown. This is in agreement with many reports in the literature for

dairy cattle. The nature of the changes during this time lapse which cause this association is unknown. The association between post-partum interval (to first service) and conception rate does not appear to be genetically influenced since the correlation calculated, using variation between cows within identical twin pairs, was not significantly less than that calculated between cows within fraternal twin pairs ($r=0.28$ for each type of twin).

Summary

Analysis of variance of the component intervals of 61 service periods from four pairs of identical and eight pairs of fraternal Hereford twins showed interval to uterine involution to be significantly shorter in the first than in the second service period whereas the intervals to first ovulation and first heat were not significantly affected by parity.

A comparison of the variances within the two types of twin pairs showed that variation in involution rate was significantly less between identical twins than between fraternal twins. This same tendency was present but not statistically significant for the intervals to first ovulation and first estrus.

A non-significant correlation of 0.14 was found between intervals to involution and to first heat. The correlation between interval to involution and conception rate at first estrus and the corresponding standard partial regression were non-significant ($r=0.08$ and $b'=0.02$). Conception rate at first service was significantly affected by interval to first estrus ($r=0.40$, $P<0.05$; $b'=0.40$, $P<0.01$). All animals were bred at first heat after calving.

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FASTING EFFECTS ON DRESSED YIELDS, SHRINKAGE, AND pH OF CONTRACTILE TISSUE IN SWINE [1]

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IT is a well established fact that hogs will usually lose weight while in transit from farm to market. This loss in weight which is commonly called shrinkage or "drift" is due to excretion and tissue shrinkage.

Bjorka (1938) in a study of over six million hogs found that excretory shrinkage took place at a rapid rate in the early part of transit, and reached a maximum after 30 to 36 hours enroute. Tissue shrinkage also began early in transit but continued at a fairly constant rate. Henning and Stout (1932) reported that hogs receiving water but no feed and slaughtered within 5 days after leaving the farm, yielded the same as those slaughtered immediately; whereas hogs held 7 days dressed less than those slaughtered immediately and showed a downward trend in dressing percent for each additional day held before slaughter, after the first 5 days. Ashby (1933), Wiley (1931) and Henning and Stout (1932) found a great variation in shrinkage and noted a definite seasonal trend with the highest shrinkage occurring in June, July and August, and lowest in January and February.

Callow (1938, 1939), Rose and Peterson (1951) and Briskey *et al.* (1959) have all reported that glycogen levels were reduced and pH of the muscle was high when animals were fatigued and/or fasted. Ingraham (1948) and Jones (1952) found a greater incidence of ham spoilage associated with high pH.

This investigation was designed to determine the amount and kind of shrinkage and the effect on muscle pH occurring when hogs are fasted.

Materials and Methods

Data reported in this paper were obtained from 84 hogs comprising 13 litters which were divided into 5 fasting groups. Sixty-five of these hogs were obtained within a 15-mile radius of the University abattoir. Litters having at least five hogs were selected in this group; they are called short haul litters throughout this paper. Nineteen hogs were purchased at one farm 160 miles from the University; these are called long haul litters throughout this paper. The litters of this group had a minimum of four pigs each. All hogs were ear notched shortly after birth to provide litter mate identification. The breeds represented were Duroc, Hampshire,

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Yorkshire and Hampshire X Yorkshire. All hogs were weighed to the nearest 0.5 lb. out of the feedlot on the same portable platform scale.

One hog per litter from the short haul group was slaughtered immediately upon arrival at the abattoir (0 hours fasting). The remaining hogs had access to water but not feed. Thereafter, one hog of each litter was killed at the end of 24, 48, 72 and 96 hours of fasting. Since it was impossible to slaughter any of the long haul pigs at zero hours of fasting, because of the time consumed in transit, the first hog of each litter was not slaughtered until the end of the first fasting period, (24 hours fasting). Additional hogs from the same litters were slaughtered at 48, 72, and 96 hours of fasting. Selections within litters for fasting intervals were made at random.

Hogs were slaughtered and dressed packer style. Dressing percent was calculated on the basis of the 48-hour chilled carcass weight and the off feed (0 hours) weight.

Weights were obtained of the viscera (gastro-intestinal tract plus the heart, liver, caul fat, trachea and spleen), the gastro-intestinal tract (esophagus, stomach, small and large intestine, pancreas, ruffle fat and bung) and individual weights of heart, liver, tongue, spleen, stomach, small intestine and large intestine. The last three were weighed both full and empty.

Each carcass was cut as described by Cole (1951). All weights were recorded to the nearest 0.1 lb. Hams were cured using the dry cure method by adding the 8–2–2 cure mixture (8 lb. salt, 2 lb. brown sugar and 2 oz. sodium nitrate) to increase the original green ham weight by 10%. The hams were cured 2 days per pound after which they were smoked for 48 hours at a constant smokehouse temperature of 110° F. pH determinations were made on the 48-hour chilled fresh ham and on the chilled smoked ham with a Model H-2 Beckman glass electrode pH meter.

Analysis of variance and correlation coefficients were calculated as outlined by Snedecor (1956). Analysis of variance was computed using the mean for each litter and fasting interval (24, 48, 72, and 96 hours). The zero hour data were not used since this interval contained none of the pigs from the long haul litters.

Results and Discussion

Thirteen genetically known litters were used in this study. Admitting the possibility of variation within litters, it was believed that the effects of feeding, handling, type, and environment were minimized by comparing litter mates.

Analysis of variance did not reveal a significant difference between the short haul and long haul litters for any of the items under study. Therefore, the short and long haul litters were combined and, for the remainder of this paper, treated as one group.

Table 1 shows that one-half of the total shrinkage occurred during the first 24 hours and 88% occurred during the first 48 hours, only 12% of the total shrinkage occurring during the last 48 hours of fasting. An average total shrinkage of 8.37% had occurred at the end of 96 hours.

Dressing percentage was not significantly affected by hours off feed (table 1), although, the average dressing percent did decrease with time off feed. This may have been due to the significant ($P<.05$) variation in dressing percent among litters. When average dressing percent was correlated with time off of feed, a significant correlation ($r=-.29$) was obtained, which would indicate that some tissue shrinkage had occurred.

Brody (1945) reported that for a 220.5-lb. hog it would require 2,654 calories for a male and 2,316 for a female to fulfill the energy requirements

TABLE 1. SLAUGHTER DATA OBTAINED FROM HOGS SLAUGHTERED AT DIFFERENT HOURS OFF FEED

Hours off feed	Number of animals	Av. off-feed weight, lb.	Av. kill weight, lb.	Total av. shrinkage, %[a]	Dressing percent[b]
0	13	220	220	0	70.13
24	18	217	208	4.15	69.97
48	17	217	201	7.37	69.55
72	18	220	203	7.73	69.45
96	18	215	197	8.37	68.78

[a] Observed differences among fasting periods significant at the 1% level.
[b] Based on off-feed weight and 48-hr. chilled carcass weight.

for a 24-hour fasting period. It might be reasoned logically that the hogs used in this study could have obtained enough energy for the first 24 hours from the loss in liver weight and from the undigested feed in the intestinal tract. Approximately one-half of the hogs used in this study were males and one-half were females. By taking an average of the calories necessary for a male (2,654) and female (2,316), it would be assumed that 2,485 calories were necessary to take care of the energy requirement for a 24-hour period, or 7,455 calories for the time interval between 24 and 96 hours of fasting. Pomeroy (1941) reported that fat was the first tissue used as a source of energy when hogs were placed on a submaintenance diet. Since fat has approximately 9 calories of energy per gram, it was estimated that 1.83 lb. of fat tissue would be necessary to supply the energy requirements for 72 hours. This would be 0.83% tissue loss for a 220.5-lb. hog. There was 1.35% lower yield for hogs fasted 96 hours as compared to those killed immediately off feed (table 1). This was fairly close to the above calculated shrinkage. If some muscle tissue or carbohydrates were used as energy, the calculated value would be even closer.

Highly significant differences among fasting periods were found for each of the following: Viscera, full G. I. tract, full stomach, full small intestine and full large intestine (table 2). These losses in weight with fasting were

TABLE 2. OFFAL DATA [a] FROM HOGS SLAUGHTERED AT DIFFERENT HOURS OFF FEED

Hours off feed	Liver [b]	Caul fat	Ruffle fat	Viscera [b]	Gastro-intestinal tract		Stomach		Small intestine		Large intestine	
					Full [b]	Empty [b]	Full [b]	Empty [b]	Full [b]	Empty [b]	Full [b]	Empty [b]
0	1.56	0.32	1.44	14.8	11.4	4.97	3.09	0.68	2.81	1.32	3.93	1.48
24	1.48	0.36	1.39	11.3	7.9	4.63	1.14	0.66	1.14	1.14	3.55	1.48
48	1.30	0.33	1.35	9.5	6.4	4.17	0.83	0.66	1.04	1.04	2.40	1.27
72	1.28	0.34	1.41	9.0	5.6	4.22	0.74	0.63	0.91	0.91	2.18	1.29
96	1.15	0.35	1.43	8.7	5.4	4.07	0.69	0.61	0.82	0.82	1.87	1.22

[a] Based on percent of off-feed weight.
[b] Observed differences among fasting periods significant at the 1% level.

probably due to digestion and assimilation of feed. Differences among fasting periods were not significant for either caul or ruffle fat. Highly significant differences among fasting periods were found for percent of each of the following: Liver, empty small and empty large intestine, whereas the empty stomach approached significance at the 5% level. It is difficult to explain fully the continued loss in weight of the empty stomach, empty small intestine and empty large intestine which occurred with prolonged fasting. The hogs had free access to water and considerable liquid was found in the gastro-intestinal tract; therefore, it was not believed that this difference was due to dehydration.

The liver was the only organ of economic importance which was significantly affected ($P<.01$) with fasting. The percent of liver gradually

TABLE 3. AVERAGE PERCENT OF VARIOUS PORK CUTS[a] AT TIME OFF FEED, AND MEAN SQUARES FOR TIME OFF FEED AND LITTERS

	Hours off feed					Mean squares[b]		
Pork cuts	0	24	48	72	96	Time	Litter	Within
Ham	13.0	13.9	14.1	14.2	13.9	0.29	3.21**	0.31
Loin	9.5	9.8	9.8	9.9	9.7	0.15	4.70**	0.21
Shoulder	11.0	11.4	11.3	11.0	11.2	0.45	1.20**	0.40
Belly	11.0	10.8	10.8	10.7	10.4	0.38	2.17**	0.18
Fat trim	17.1	15.5	15.1	15.1	15.2	0.40	27.30**	1.87

[a] Percent based upon off feed weight.
[b] Excludes 0 time fasting; all other fasting intervals have one hog per litter represented.
** Denotes significance at $P<.01$.

decreased with continual fasting. Thus it might be assumed logically that the loss in weight of the liver was due to glycogen depletion. Wilcox *et al.* (1953), Ingraham (1948), Rose and Peterson (1951), Callow (1938, 1939) and Bate-Smith (1938, 1948) have found the liver to be a storehouse of glycogen which becomes a primary energy source when animals are exercised or fasted.

No significant differences among fasting periods were found in percent of the various wholesale cuts. Table 3 lists the average percent cut out of various pork cuts.

Highly significant differences ($P<.01$) were found among litters for the percent yields of the various wholesale pork cuts (table 3). This would indicate that hog carcass cut out, based upon off feed weight, is affected more by type and breed differences than by the length of fasting. Although evidence of some tissue shrinkage was observed, it did not affect the percent yield of pork cuts significantly. This could be attributed to (1) cutting error or variation, (2) the small loss from tissue shrinkage, and (3) sensitivity of weights taken.

Differences among pH determinations for the different fasting periods were not significant for either the fresh or cured and smoked ham samples.

The range in pH for fresh ham muscle was 5.3 to 5.4, whereas the pH range for cured and smoked ham was 5.4 to 5.5. Previous workers (Callow 1938, 1939; Rose and Peterson 1953; Briskey *et al.*, 1959) studying the effects of fatigue upon muscle glycogen levels and muscle pH, have all reported a reduction in the glycogen levels of the muscle and an increase in muscle pH when animals were fatigued. Apparently in this study adequate quantities of glycogen were present in the muscle tissue of fasted hogs to maintain a relatively low pH.

Summary

Eighty-four hogs comprising 13 litters were divided into 5 groups to study fasting effects of excretory and tissue shrinkage. The first group was slaughtered immediately off feed, and groups, 2, 3, 4 and 5 were slaughtered at the end of 24, 48, 72 and 96 hours of fasting, respectively.

During the four-day fasting regime, nearly 50% of the total shrinkage occurred by the end of 24 hours and 88% by the end of 48 hours.

Dressing percentage was not significantly affected by fasting when using off-feed weights. However, a significant correlation ($r=-.29$) was noted between the dressing percent and fasting time, which denotes a small loss in carcass weight that could be attributed to tissue shrinkage.

Highly significant differences among fasting periods were found for each of the following: Liver, full viscera, full gastro-intestinal tract, full stomach, full small intestine, full large intestine, empty gastro-intestinal tract, empty small intestine and empty large intestine. The liver was the only one of the above items in which a monetary loss would be incurred.

The yield of pork cuts was not significantly affected by fasting; whereas differences between litters significantly affected the percent of pork wholesale cuts. The pH of muscle tissue was not significantly affected by fasting time.

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INTERRELATIONSHIPS BETWEEN CALCIUM, ZINC, IRON AND COPPER IN SWINE FEEDING [1]

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TRACE minerals have long been known to be of importance in swine nutrition. The early Wisconsin work established the importance of iron and copper in blood formation. More recently Speer *et al.* (1952) reported a stimulation of growth in swine fed a combination of trace minerals, including iron, manganese, copper, cobalt and zinc. British workers (Barber *et al.*, 1955a, 1955b, 1955c, 1957) have reported a consistent and significant effect upon growth of swine resulting from the feeding of 0.1% copper sulfate. Other publications (Bass *et al.*, 1956; Davis, 1958) have indicated a rather irregular growth effect and a possible toxicity when copper was fed to swine. The relationship of zinc to swine growth and parakeratosis has been reported by numerous workers (Luecke *et al.*, 1956, 1957; Lewis *et al.*, 1956, 1957; Tucker and Salmon, 1955).

The objectives of the work reported here were to determine the effect of certain trace elements on the growth of weanling pigs and the possible relationship between these elements and the incidence of parakeratosis. In addition, measurements were to be made of the cellular constituents of the blood, serum proteins and serum alkaline phosphatase.

Experimental

Three separate experiments involving a total of 158 weanling pigs were conducted. The general procedure for lotting, management and record keeping was essentially the same for all three experiments. All lots were made as uniform as possible for weight, sex, breed, litter and thriftiness. The pigs were maintained in concrete floored pens, and they had free access to water and feed at all times. They were vaccinated for hog cholera and treated for both internal and external parasites during the first two weeks of the experiment. Feed and growth data were collected at two-week intervals. The composition of the control rations used in each experiment is shown in table 1. The major variant between the different control rations was the percent calcium.

Analysis of variance (Snedecor, 1956) was used to evaluate the differences obtained in the various experiments.

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[2] Departments of Animal Husbandry and Agricultural Chemistry.

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Experiment I. Fifty weanling pigs, approximately seven weeks of age, were used in this experiment. The ration treatments were as follows: lot 31, control (0.55% Ca); lot 32, control + zinc carbonate (50 p.p.m. Zn); lot 33, control + ferrous sulfate (100 p.p.m. Fe); lot 34, control + zinc (50 p.p.m.) and iron (100 p.p.m.); and lot 35, control + copper sulfate (125 p.p.m. Cu).

Hemoglobin and hematocrit values were determined at the beginning of the trial, during the seventh week, and at the end of the trial. Hemoglobin

TABLE 1. PERCENTAGE COMPOSITION OF CONTROL RATIONS

Experiment	I	II	III	III
Corn	77.425	75.475	77.375	75.375
Soybean oil meal	16.00	16.00	16.00	16.00
Meat and bone scrap	2.00	2.00	2.00	2.00
Fishmeal	1.00	1.00	1.00	1.00
Alfalfa meal	2.00	2.00	2.00	2.00
Limestone	0.50	2.50	0.70	2.70
Dicalcium phosphate	0.30	0.30	0.20	0.20
Iodized salt	0.50	0.50	0.50	0.50
B-vitamin concentrate	0.10	0.10	0.10	0.10
Vitamin A and D concentrate	0.025	0.025	0.025	0.025
Vitamin B_{12} concentrate	0.05	0.05	0.05	0.05
Antibiotic concentrate	0.10	0.05	0.05	0.05
Composition by analysis[a]				
Protein, %	17.31[b]	16.56[b]	16.38[b]	16.44[b]
Ca, %	0.55	1.05	0.55	1.31
P, %	0.55	0.55	0.50	0.51
Zn, ppm	28.1	35.7	38.7	34.5
Fe, ppm	157.0	122.0	....	....
Cu, ppm	8.0	12.0	9.0	23.0

[a] A.O.A.C. methods used throughout.
[b] Protein reduced to 13.0% when pigs reached 125 lb.

was determined by the cyanmethemoglobin method of Crosby *et al.* (1954). Hematocrit was determined by the micro-method described by McGovern *et al.* (1955). Blood samples were centrifuged for 5 minutes at 10,000 r.p.m. in an International "Hemacrit" centrifuge.

Serum alkaline phosphatase activities were measured at the second bleeding; the method used was that of Bessey *et al.* (1946), the substrate being p-nitrophenyl phosphate. The activity of the enzyme is defined as that amount of phosphatase which will liberate 1 mM (millimole) of p-nitrophenol per hour per liter of serum. Thus, the results are expressed in units per liter of serum.

Experiment II. Forty-eight pigs were allotted into six treatment groups. In this experiment the calcium content of the control ration was increased to 1.05%, a level which in the absence of added zinc has consistently produced parakeratosis (Luecke *et al.*, 1956, 1957). The ration treatments

were as follows: lot 39, control (1.05% Ca); lot 40, control + zinc carbonate (50 p.p.m. Zn); lot 41, control + ferrous sulfate (100 p.p.m. Fe); lot 42, control + zinc (50 p.p.m.) and iron (100 p.p.m.); lot 43, control + copper sulfate (125 p.p.m. Cu); and lot 44, control + copper (125 p.p.m.) and zinc (50 p.p.m.).

Hemoglobin, hematocrit, serum alkaline phosphatase, and serum protein determinations were made three times during the experiment; at the start, after 53 days, and when the pigs were slaughtered. Total serum protein was determined by the biuret procedure accepted by the American Association of Clinical Chemists (Reiner, 1953). Electrophoretic separation of serum proteins was accomplished on a Spinco Model R paper electrophoresis system (Spinco Technical Bulletin 6026A).

Livers were also obtained for spectrographic analysis. The results of these determinations will be reported in a subsequent paper.

Experiment III. Six ration treatments involving two calcium levels (0.55 and 1.31%) with either added zinc (75 p.p.m. Zn) or added copper (125 p.p.m. Cu) were used. There were no combinations of trace element supplementation in this experiment. Ten uniform weanling pigs were allotted to each treatment.

Hemoglobin, hematocrit, serum alkaline phosphatase and serum protein determinations were made at the conclusion of the trial (84 days).

Results and Discussion

Experiment I. A summary of the results obtained in Experiment I is presented in table 2. Differences in daily gain resulting from the addition of the various trace minerals to the control ration were higly significant ($P<.01$) in all cases. The fastest gains were made by the pigs receiving either supplemental zinc (50 p.p.m.) or copper (125 p.p.m.) with somewhat poorer gains being made by the pigs receiving either iron (100 p.p.m.) or a combination of zinc and iron.

The fact that the combination of zinc and iron was less effective than zinc alone suggests an antagonism between these two elements. The answer may be in the variability of the animals used. During the course of the experiment it was necessary to remove four pigs from this lot for unusually poor performance. These animals were autopsied and post mortem examinations revealed conditions unrelated to the experimental treatments.

The poor growth of the pigs on the control ration was accompanied by a high incidence of parakeratosis, which was severe in four of the six pigs developing the skin lesions. It should be noted that the control rations contained only 0.55% Ca, a level under that usually considered to predispose parakeratosis. While this finding is not common, others have reported it (Stevenson and Earle, 1956; Lewis *et al.*, 1957; Hoefer *et al.*, 1956, 1958a). National Research Council (Beeson *et al.*, 1953) recom-

mendations for calcium are 0.8 and 0.65% for 25- and 50-pound pigs, respectively.

The fact that no parakeratosis occurred in the zinc fed pigs was to be expected, but the presence of only one case in the iron group and none in the copper fed pigs suggests that these elements may also be related in some manner to this disease. The pigs in lot 35 (Cu) were particularly thrifty in appearance with excellent skin and hair coat condition. The authors have reported (Hoefer *et al.*, 1958b) that copper may be helpful in preventing parakeratosis.

TABLE 2. SUMMARY OF RESULTS OF EXPERIMENT I (91 DAYS)

Lot	31		32		33		34		35	
Treatment	Control (0.55% Ca)		+Zn		+Fe		+Zn+Fe		+Cu	
No. pigs	10		10		10		6[a]		9[a]	
Initial wt., lb.	28.5		28.4		28.3		28.5		28.3	
Final wt., lb.	120.1		163.9		148.5		150.7		163.7	
Daily gain, lb.	1.01	0.12	1.49	0.06**	1.32	0.04**	1.34	0.03**	1.49	0.06**
Feed/lb. gain, lb.	3.03		3.07		3.04		3.03		3.07	
Parakeratosis, %	60		0		10		0		0	
Hemoglobin, gm./100 ml.										
Initial	11.1	0.5[b]	10.9	0.5	10.2	0.5	11.1	0.5	11.8	0.3
47 days	11.1	0.3	12.0	0.4	11.2	0.2	11.9	0.4	12.0	0.1
Final	11.4	0.4	12.0	0.4	12.0	0.3	12.0	0.4	11.4	0.6
Hematocrit, %										
Initial	37.5	1.1	36.7	1.1	35.8	0.8	37.1	1.2	39.0	0.9
47 days	36.3	0.9	38.6	1.1	36.7	0.7	37.6	1.0	38.1	0.3
Final	36.6	0.9	37.0	1.6	38.3	0.9	36.5	1.4	36.3	1.9
S.A. Phosphatase, units/liter										
47 days	0.91	0.07	3.10	0.32**	1.21	0.21	3.21	0.30**	1.97	0.15**

[a] Four pigs removed from lot 34 and one from lot 35 for reasons unrelated to the experiment.
[b] Values in second column under headings are ± standard error of the mean.
** $P<.01$.
* $P<.05$.

There were no significant differences in either hemoglobin or hematocrit values as related to the various treatments.

Serum alkaline phosphatase activities were significantly ($P<.01$) higher in the pigs receiving zinc as compared with either the control or the copper-fed pigs. The values for the copper pigs were intermediate between the zinc and controls but were also significantly higher ($P<.01$) than the controls. The relationship between phosphatase and parakeratosis has been reported by Luecke *et al.* (1957, 1958).

Experiment II. The results of Experiment II are reported in tables 3 and 4. Because most of the evidence reported supports the thesis that high calcium rations are parakeratotic producing and that skin lesions are less likely to develop on low calcium diets, it was decided in Experiment II to increase the calcium content of the control ration to 1.05% in order to test more critically the possible relationship of copper and iron to parakeratosis.

TABLE 3. SUMMARY OF RESULTS OF EXPERIMENT II (98 DAYS)

Lot	39	40	41	42	43	44
Treatment	Control (1.05% Ca)	+Zn	+Fe	+Zn+Fe	+Cu	+Zn+Cu
No. pigs	7[a]	7[b]	7[c]	7[d]	8	8
Initial wt., lb.	24.1	23.7	25.1	25.0	24.5	24.2
Final wt., lb.	75.6	156.7	90.4	146.1	161.6	157.8
Daily gain, lb.	0.52 0.12	1.36 0.07**	0.67 0.15	1.24 0.04**	1.40 0.08**	1.36 0.06**
Feed/lb. gain, lb.	4.53	3.48	4.12	3.65	3.56	3.52
Parakeratosis, %	100	0	100	0	0	0
Hemoglobin, gm./100 ml.						
Initial	9.3 0.4[e]	9.5 0.5	9.7 0.4	9.7 0.3	9.7 0.3	10.2 0.3
53 days	11.8 0.4	12.2 0.3	11.9 0.4	12.3 0.3	13.1 0.3*	13.4 0.3**
Final	12.5 0.3	13.7 0.3*	12.0 0.5	14.0 0.2**	13.8 0.3*	14.5 0.2**
Hematocrit, %						
Initial	32.9 1.0	33.3 1.2	34.3 1.1	33.7 1.1	33.1 0.9	34.8 0.9
53 days	38.2 0.8	40.1 0.8	39.0 1.1	39.0 0.8	40.8 1.2	42.5 1.0**
Final	39.0 0.8	42.4 0.4	38.2 1.4	43.0 0.3**	42.4 1.0	44.1 1.0**
S.A. phosphatase, units/liter						
Initial	3.69 0.33	3.45 0.34	2.97 0.22	2.98 0.43	4.35 0.31	4.02 0.45
53 days	0.67 0.13	4.02 0.27**	1.47 0.17	4.29 0.43**	2.73 0.26**	5.15 0.13**
Final	1.39 0.38	3.96 0.17**	2.27 0.44*	3.76 0.22**	2.08 0.26	3.49 0.18**

[a] One pig died.
[b] Pig removed with rupture.
[c] One pig died.
[d] One pig removed—losing weight.
[e] Values in second column under headings are ± standard error of the mean.
** $P<.01$.
* $P<.05$.

TABLE 4. SERUM PROTEIN VALUES FOR PIGS IN EXPERIMENT II (98 DAYS)

Lot	39	40	41	42	43	44
Treatment	Control (1.05% Ca)	+Zn	+Fe	+Zn+Fe	+Cu	+Zn+Cu
Initial values						
Total serum protein, gm./100 ml.	5.79 0.16[a]	5.58 0.11	5.71 0.15	5.40 0.17	5.62 0.14	5.48 0.10
Gamma globulin, %	15.1 1.3	14.3 0.6	14.2 0.6	12.8 0.5	13.2 0.7	16.5 1.3
Beta globulin, %	14.4 0.7	13.9 1.1	15.6 1.2	14.4 0.5	13.8 0.6	12.6 0.9
Alpha globulin, %	30.3 0.8	29.5 1.2	27.9 0.8	30.9 1.6	30.8 0.8	28.1 1.4
Albumin, %	40.1 1.7	42.3 1.7	42.4 1.9	41.8 2.0	42.1 0.9	42.8 1.0
Values at 53 days						
Total serum protein, gm./100 ml.	7.42 0.15	6.99 0.20	6.88 0.14*	6.62 0.28**	6.79 0.15*	6.71 0.19*
Gamma globulin, %	31.4 1.7	24.6 1.6**	25.9 1.5*	22.8 2.0**	22.1 1.5**	24.7 1.9**
Beta globulin, %	12.1 0.7	10.6 0.8	11.3 0.7	12.5 0.7	12.1 0.4	10.9 0.7
Alpha globulin, %	24.5 0.9	23.9 1.3	23.6 2.1	25.5 1.5	22.6 0.9	22.4 1.3
Albumin, %	32.0 1.8	40.9 2.9*	39.1 1.6*	40.4 3.0*	43.2 3.0**	42.0 2.2**
Final values						
Total serum protein gm./100 ml.	7.46 0.17	7.00 0.11*	7.11 0.20	7.05 0.12	7.09 0.10	7.03 0.14*
Gamma globulin, %	38.6 3.7	21.8 0.6**	28.5 2.7**	21.4 1.4**	24.0 1.1**	21.0 0.7**
Beta globulin, %	13.0 0.4	12.9 0.9	12.3 0.9	12.4 0.9	12.0 0.6	12.6 0.3
Alpha globulin, %	21.3 1.3	17.3 1.1	21.5 2.2	19.4 1.1	19.7 1.0	18.3 0.7
Albumin, %	27.0 3.0	48.0 1.1**	37.7 4.2**	46.8 0.7**	44.2 1.6**	48.2 0.8**

[a] Values in second column under headings are ± standard error of the mean.
** $P<.01$.
* $P<.05$.

Again, zinc and copper had a highly significant effect on rate of gain and no parakeratosis developed in either treatment. All the pigs on the control ration developed skin lesions (very severe in six of the seven pigs), but unlike Experiment I the iron was completely ineffective in preventing the disease.

In this experiment both zinc and iron, and zinc and copper were combined as treatments. In the case of zinc and copper (lot 44) the two elements together were no more effective than zinc or copper alone, but, again as in Experiment I, the combination of zinc and iron was somewhat poorer than zinc alone. An antagonism between zinc and copper at least with respect to liver storage has been reported (Allen *et al.*, 1958; Davis, 1958; Van Reen, 1957).

Hemoglobin and hematocrit values were increased in a significant manner at both the second and final bleedings by certain of the trace mineral treatments.

Serum alkaline phosphatase values were markedly increased at the second period by all trace mineral additions ($P<.01$ for Zn and Cu; $P<.05$ for Fe). The effect was less at the final bleedings. The parakeratotic lesions were most severe at about 8 weeks and there was some recovery thereafter, even though there was no therapy. The increases in phosphatase values at the final bleeding seemed to reflect the general improvement in the pigs.

Total serum protein and the gamma globulin and albumin fractions were influenced in a significant manner by all trace mineral treatments as indicated in table 4. At the second bleeding (53 days) all lots except zinc (lot 40) had a lower total serum protein ($P<.05$, lots 41, 43, 44; $P<.01$, lot 42) than the control lot (lot 39). At the same bleeding the gamma globulin fraction was lower ($P<.01$, lots 40, 42, 43, 44; $P<.05$, lot 41) and the albumin fraction was higher for all supplemented lots ($P<.01$, lots 43, 44; $P<.05$, lots 40, 41, 42).

Final values showed a decrease ($P<.01$) in the gamma globulins and an increase ($P<.01$) in the albumin fraction for all supplemented lots. With regard to total serum protein, lot 40 (Zn) and lot 44 (Cu+Zn) were lower ($P<.05$) than the control lot.

None of the experimental treatments had any apparent effect on the beta and alpha globulin fractions.

Experiment III. Results for Experiment III are reported in table 5. The control rations in this experiment contained 0.55 and 1.31% calcium. Each control ration was supplemented with zinc and copper at levels of 75 and 125 p.p.m., respectively.

At the low calcium level there was a non-significant improvement in rate of gain when either zinc (lot 46) or copper (lot 47) was added to the ration. Only one mild case of parakeratosis developed in the control lot (lot 45) and none in the zinc or copper supplemented groups. This is

TABLE 5. SUMMARY OF RESULTS OF EXPERIMENT III (84 DAYS)

Calcium, %	0.55						1.31					
Lot	45		46		47		48		49		50	
Treatment	Control		+Zn		+Cu		Control		+Zn		+Cu	
No. pigs	10		10		10		10		10		10	
Initial wt., lb:	32.3		32.3		32.5		32.4		32.8		32.3	
Final wt., lb.	163.2		165.7		169.5		70.0		141.4		123.2	
Daily gain, lb.	1.56	0.05** [a]	1.59	0.07**	1.63	0.05**	0.45	0.14	1.29	0.05**	1.08	0.11**
Feed/lb. gain, lb.	3.13		3.11		3.19		4.23		3.58		3.53	
Parakeratosis, %	10		0		0		90		0		50	
Hemoglobin, gm./100 ml.	14.0	0.2**	14.4	0.4**	13.8	0.4**	12.4	0.5	14.8	0.2**	13.3	0.4
Hematocrit, %	42.4	0.4**	43.4	0.9**	41.7	0.9**	38.7	1.4	44.5	0.6**	41.9	1.1*
S.A. phosphatase, units/liter	1.38	0.12	3.54	0.21	1.66	0.22	1.38	0.30	3.94	0.16**	1.54	0.19
Total serum protein, gm./100 ml.	6.63	0.13	6.80	0.11	6.70	0.13	6.60	0.10	6.73	0.12	6.74	0.16
Gamma globulin, %	19.8	0.6**	18.5	0.6**	17.8	0.7**	26.2	2.7	19.7	1.1**	24.2	2.7
Beta globulin, %	11.7	0.6	12.1	0.2	14.0	1.4	13.8	0.5	13.5	0.7	12.7	0.3
Alpha globulin, %	18.2	0.7**	18.3	0.5**	20.2	0.6	21.3	1.0	20.5	0.4	21.4	0.8
Albumin, %	50.3	1.1**	51.1	0.8**	48.0	1.1**	38.7	2.9	46.3	1.4**	41.7	3.0

[a] Values in second column under headings are ± standard error of the mean.
** $P<.01$.
* $P<.05$.

in contrast to the high incidence of severe parakeratosis that developed in Experiment I (lot 31) on a very similar ration.

The pigs receiving the high calcium (1.31%) control ration (lot 48) made very poor growth. All but one pig in this lot were afflicted with severe parakeratosis. Supplementation of the control ration with zinc (75 p.p.m.) resulted in improved growth ($P<.01$) and completely suppressed the development of skin lesions. The effect of copper on growth, when added to the high calcium control ration, was less than that of zinc but was still highly significant ($P<.01$). An important finding in Experiment III was the development of fairly severe skin lesions in 50% of the pigs fed copper. The lesions were far less extensive in lot 50 than in lot 48, nevertheless, parakeratosis was definitely present in the copper-fed pigs. No explanation is available for this finding which is in conflict with the results obtained in Experiments I and II, where copper was 100% effective in preventing parakeratosis.

All the pigs on the low calcium rations (lots 45, 46 and 47) and the high calcium plus zinc group (lot 49) maintained significantly ($P<.01$) higher hemoglobin values than the pigs receiving the high calcium control ration (lot 48). Hematocrit differences were essentially similar to those for hemoglobin except that lot 50 (high Ca+Cu) had a higher hematocrit ($P<.05$) than lot 48, whereas the hemoglobin difference between these two lots was not significant.

Serum alkaline phosphatase values were much higher ($P<.01$) for the zinc-fed pigs regardless of the calcium level. Although, there was no difference between the control lots (lot 45 versus 48) there was considerably more variation in the high calcium group. The symptoms of parakeratosis tend to reach a peak at about 6–10 weeks, then there is some recovery accompanied by an increase in serum alkaline phosphatase activity. This may account for the similarity in averages between the high and low calcium lots.

An examination of the blood serum protein data shows that the lots with a high incidence of parakeratosis (lots 48 and 50) had a higher ($P<.01$) gamma globulin fraction and a lower ($P<.01$) albumin fraction than the lots free of parakeratotic lesions. The alpha globulins were significantly lower in the low calcium control (lot 45) and where zinc was added to the low calcium ration (lot 46).

Further research is needed to clarify the relationship between the blood serum protein fractions and the incidence and severity of parakeratosis. However, with respect to serum alkaline phosphatase levels, the data do indicate a significant drop in the activity of this enzyme in pigs with parakeratosis. In addition it would appear that zinc supplementation increases the activity of the enzyme above that produced by iron or copper supplementation. In this connection Mathies (1958) has prepared a highly purified preparation of alkaline phosphatase from swine kidneys and found it to contain significant amounts of zinc (0.26%). Furthermore, removal

of zinc from this preparation below a level of 0.15% caused a reduction in activity. It thus seems possible that zinc may be a component of this enzyme, and would tend to explain the lower values observed in pigs with parakeratosis.

Summary

Three experiments involving a total of 158 weanling pigs were conducted to study the effect of adding zinc (50 or 75 p.p.m.), iron (100 p.p.m.) and copper (125 p.p.m.) to control rations varying in calcium level (0.55, 1.05 and 1.31%). Combinations of zinc and iron, and zinc and copper were also used in two of the experiments.

Parakeratosis occurred at all three calcium levels; it was completely prevented by the addition of zinc. Iron was ineffective at the higher calcium levels in controlling parakeratosis. Copper had a significant effect on growth particularly at the higher calcium levels. Although less effective than zinc, copper reduced the incidence and severity of parakeratosis.

In two of the three experiments the addition of the trace elements resulted in a significant increase in hemoglobin and hematocrit.

Serum alkaline phosphatase levels were increased in a highly significant manner by zinc. Copper had a positive but lesser effect than zinc on these levels.

Blood serum proteins, particularly the gamma globulin and albumin fractions, were significantly affected by the trace elements.

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EFFECT OF ARSANILIC ACID IN COUNTERACTING SELENIUM POISONING IN BEEF CATTLE

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IT has been shown that arsanilic acid, an accepted feed additive for swine and poultry, gives partial protection against selenium poisoning in rats (Hendrick *et al.*, 1953) in growing chicks (Carlson *et al.*, 1954) and in swine (Wahlstrom *et al.*, 1955). A preliminary report on the effect of arsanilic acid in preventing selenium poisoning in cattle has been published by Dinkel *et al.* (1957). Following that report, further studies were conducted to determine the effectiveness of arsanilic acid in counteracting selenium poisoning in range beef cattle. The results of feedlot and of summer grazing studies are reported here.

Experimental Procedure

Feedlot Trials. Two feedlot trials were conducted with Hereford calves produced in the Experiment Station herd. All of the calves had been on seleniferous range since birth and many of them showed symptoms of selenium poisoning. The basal ration for all lots was composed of a mixture of 35% rolled whole oats, 30% ground shell corn, 30% chopped alfalfa-brome hay and 5% linseed oil meal. This basal ration and a salt-bonemeal mixture were fed free-choice. Selenium was added to the basal ration as sodium selenite. The sodium selenite was dissolved in a water-alcohol solution and sprinkled on a dried corn premix prior to its addition. The arsanilic acid (Pro-Gen 20%, Abbott Laboratories) was mixed with the premix prior to addition to the ration.

In the first trial, 24 heifer and 12 steer calves were randomly allotted to three treatments. Lot 1, which served as control for the experiment, received the basal ration with no additions. Lot 2 received the basal ration plus sodium selenite added to furnish 12 p.p.m. of selenium. Lot 3 received the basal ration plus 12 p.p.m. of selenite selenium and 0.01% of arsanilic acid. The calves were weighed and observed for visible selenium poisoning symptoms at the beginning, at intervals throughout the trial, and after 140 days when the trial was concluded. In making these observations, the severity of symptoms was scored subjectively. The scores ranged from 1 to 13, a score of 1 indicating the most extreme symptoms and a score

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of 13 indicating no symptoms. The scoring was always done by the same person.

In the second feedlot trial, 25 calves were divided into two lots, lot 1 with seven steers and six heifers and lot 2 with six steers and six heifers. Lot 1 was fed the basal ration plus 12 p.p.m. of selenite selenium. Lot 2 received the basal ration with 12 p.p.m. of selenium plus 0.01% of arsanilic acid. The rations were again fed free-choice and the animals were weighed and scored at the beginning, at various intervals, and at 139 days when the trial was concluded.

Summer Grazing Trial. For this trial, 48 yearling Hereford steers were obtained from an area with no previous history of selenium poisoning and placed on experiment June 1, 7 days after delivery. They were arrayed by weight and divided into six lots, two treatments replicated three times. The steers were allotted to six seleniferous pastures for the summer grazing season and were rotated bi-weekly among the pastures in order to minimize any differences in the selenium content of the various grasses. All lots received 1 lb. of ground, pelleted corn per head daily. For lots 2, 4 and 6, the pellets contained 0.12% of arsanilic acid. This level was selected because feedlot trials had demonstrated the safety of an average daily intake of arsanilic acid equivalent to what would be furnished under these conditions.

It had been demonstrated on previous occasions that grazing of these pastures would result in selenium poisoning symptoms in at least a part of the animals. The steers showed no symptoms of selenium poisoning at the beginning of the trial; they were all given a score of 13 at that time. They were weighed and regularly observed for symptoms during the trial and at its termination after 139 days.

Results and Discussion

Feedlot Trials. The results are summarized in table 1. In Trial 1 the addition of selenium to the ration (lot 2) decreased the average daily gain by 0.37 lb. The animals on the selenium ration containing arsanilic acid (lot 3) gained 0.16 lb. per day more than those in lot 2. In trial 2 the difference between these two treatments was 0.08 lb. in favor of the arsanilic acid additive. These differences are not large enough to be statistically significant (Snedecor, 1956). In Trial 1, animals in lot 1 largely recovered during the course of the trial from the conditions they exhibited at its beginning. Animals in lot 2, receiving 12 p.p.m. of added selenium, did not recover from initial selenium damage; in fact, the severity of their symptoms increased. When arsanilic acid was fed along with the seleniferous ration (lot 3) the number of animals showing symptoms decreased and so did the average severity of selenium damage for the lot.

In lot 1 of the second feedlot trial, the number of animals showing symptoms of toxicity and the severity of the symptoms increased during

the experiment. Lot 2, receiving 0.01% arsanilic acid, showed no increase in the number of animals affected nor in severity of damage during the same period.

The results of these two trials did not conclusively demonstrate a protective effect for arsanilic acid. No toxic effects due to the arsenicals were observed at any time during the experiments. The average daily intake of the arsenical was over 500 mg. per animal per day in both experiments. In previous work (Dinkel *et al.*, 1957) arsanilic acid was fed at a level

TABLE 1. EFFECT OF ARSANILIC ACID IN FEEDLOT TRIALS

Trial	1	1	1	2	2
Treatment	Basal	Basal+12 p.p.m. Se	Basal +12 p.p.m. Se+0.01% arsanilic acid	Basal+12 p.p.m. Se	Basal +12 p.p.m. Se+0.01% arsanilic acid
Lot number	1	2	3	1	2
No. of animals	12	11[a]	12	13	12
Av. initial wt., lb.	366	376	377	346	352
Av. final wt., lb.	622	582	605	597	613
Av. daily gain, lb.	1.85	1.48	1.64	1.79	1.87
Feed/100 lb. gain, lb.	693	727	742	650	683
No. showing symptoms:					
Start	11	8	11	5	3
Finish	1	8	5	7	3
Severity of symptoms:[b]					
Start	10.9	11.0	9.4	12.6	12.7
Finish	12.8	10.2	11.9	8.7	12.4

[a] Records for one steer not used because it died from shipping fever after the experiment was under way.

[b] A value of 13 represents no symptoms, a value of 1 the most severe.

of approximately 540 mg. per animal per day for 319 days. The calves averaged 380 lb. at the beginning of the period and 670 lb. at the end and showed no signs of arsenical toxicity.

Summer Grazing Trial. While the feedlot trials reported here are helpful in assessing the value of arsanilic acid as a selenium counteractant, almost all of the damage to cattle from selenium occurs in range animals. Preventive measures must, therefore, be tailored to range conditions if they are to be effective. Further, the use of naturally seleniferous range grasses instead of artificially selenized rations is a more realistic approach.

The results of the summer grazing trial are presented in table 2. Unfortunately, conditions did not permit a treatment in which animals were pastured on non-seleniferous range. Those animals receiving arsanilic acid (lots 2, 4 and 6) gained 0.16 lb. per day more than those not receiving it (lots 1, 3 and 5). This difference was not statistically significant. Fewer animals in the arsanilic acid lots showed symptoms than in the control

lots. These differences may not necessarily be due to a protective effect of the arsanilic acid. With the small numbers used, the control lots might have received, by chance, a higher proportion of animals susceptible to selenium poisoning. There was very little difference in the average score for severity of selenium damage.

Results of the grazing experiment are not in close agreement with those reported by Dinkel *et al.* (1957). In the earlier study arsanilic acid exhibited a protective effect against selenium toxicity. However, the animals used in the earlier study had been on a seleniferous ration with a similar arsanilic acid treatment for about 6 months before the start of the experi-

TABLE 2. EFFECT OF ARSANILIC ACID IN SUMMER GRAZING TRIAL

Treatment	Control			Arsanilic acid		
Lot number	1	3	5	2	4	6
No. of animals	8	8	8	8	8	8
Av. initial wt., lb.	559	577	571	561	566	557
Av. final wt., lb.	740	783	742	771	782	756
Av. daily gain, lb.[a]	1.31	1.49	1.24	1.52	1.56	1.45
No. showingsymptoms:						
Start	0	0	0	0	0	0
Finish	2	1	3	0	2	1
Severity of symptoms:						
Start	13.0	13.0	13.0	13.0	13.0	13.0
Finish[b]	12.6	12.6	11.5	13.0	11.9	11.8

[a] Averages of control and arsanilic acid groups were 1.35 and 1.51, respectively.
[b] Averages of control and arsanilic acid groups were 12.2 and 12.3, respectively.

ment, allowing ample time for the toxic effects of selenium and any counteracting effect of arsanilic acid to be expressed. In the present study the animals had not been exposed either to toxic levels of selenium or to arsanilic acid prior to the beginning of the trial.

Treatment effects observed in this grazing study, as measured by rate of gain and by changes in visible symptoms of selenium poisoning, were not large enough to be statistically significant. Until a practical means can be devised for getting arsanilic acid to the cattle continuously and in controlled amounts while they are on pasture there is no basis for recommending its use.

Summary

Three trials, two in the feedlot and one summer grazing, were conducted to determine the effectiveness of arsanilic acid in preventing selenium poisoning in beef cattle. The addition of 0.01% of arsanilic acid to a ration containing 12 p.p.m. of selenite selenium appeared to increase rate of gain and reduce slightly selenium poisoning symptoms. In the grazing trial, feeding 550 mg. of arsanilic acid per day appeared to increase daily gains

in steers on naturally seleniferous range 0.16 lb. Treatment differences were not statistically significant in either the feedlot trials or the summer grazing study. No signs of arsenical toxicity were noted during the course of the experiments.

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A STUDY OF LAMB MORTALITY IN A WESTERN RANGE FLOCK. I. AUTOPSY FINDINGS ON 1051 LAMBS [1]

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NUMEROUS publications indicate lamb mortality is one of the major causes of lowered productivity of sheep. Mortality rates have been reported as high as 36.4% (Moule, 1954) and as low as 10% (Matthews and Ogden, 1957). Other published reports indicate the mortality rate of lambs falls somewhere within this range (Venkatachalam *et al.*, 1949; McFarlane, 1954; U.S.D.A., 1956).

The purpose of this study was to determine the rate of mortality in a range flock and to determine the cause of death by autopsy of lambs dying the first 45 days of the lambing period.

Procedure

These data were obtained from two flocks of sheep which were owned by the Montana Agricultural Experiment Station. One flock consisted of purebred Rambouillet, Targhee, and Columbia ewes and the other flock consisted of grade ewes of the same breeds. During the years of the study the purebred flock varied in total numbers from 600 to 850 and the grade flock varied in total numbers from 800 to 1000.

The ewes in the grade flock were herded during the late fall and winter on open foothill range. Each morning the flock was separated by means of cutting chutes into various lots for supplemental pellet feeding. The ewes were taken off winter range in early April, moved to lambing quarters and through lambing were fed alfalfa hay supplemented with a 20% protein pellet fed at the rate of ½ lb. per head per day. Lambing began in the purebred flock about April 10 each year and in the grade flock about April 20. The lambing plant and management were typical of that used under shed lambing conditions in Montana. Ewes with twins and ewes with single lambs were kept separate after lambing until shearing. After shearing all purebred ewes and lambs were combined into one flock and all grade ewes and lambs were handled likewise.

During 1952 and 1954 the purebred flock went through the same shed lambing plant as the grade flock. During 1953 the purebred flock was shed lambed in a different area, but lambing management was similar.

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Both grade and purebred flocks grazed on forest allotments beginning July 1 until the last week in August. Purebred lambs were weaned the last week in August and grade lambs were weaned the first week in September. Lambs up to 45 days of age were presented for autopsy during the study. Lambs born dead are included as lamb losses in this report.

Results and Discussion

The total lambs born during the three years of the study was 7191. The total death loss of lambs from birth to weaning was 1693, 23.5% of the total lambs born. Autopsies were performed on 1051 lambs, 14.7% of the total number of lambs born or 62% of those that died (table 1).

The number of lambs under each autopsy classification and the percent each represents of the total lambs born are listed under table 2. Seventy-two percent of the lamb losses fell into five major categories—pneumonia, no visible lesions, atelectasis, starvation and dysentery. The remainder

TABLE 1. LAMB MORTALITY IN THE MONTANA AGRICULTURAL EXPERIMENT STATION RANGE FLOCK

Item	In the year—						Total	
	1952		1953		1954			
	no.	%	no.	%	no.	%	no.	%
Lambs born	2696	....	2515	....	1980	....	7191	....
Total death	665	24.6	601	23.8	427	21.5	1693	23.5
Total autopsies	353	13.9	451	17.9	247	12.4	1051	14.7

of the losses were attributed to delayed parturition, enterotoxemia, preparatum death, liver rupture, anomalies, umbilical hemorrhage, navel infection, hemorrhagic enteritis and miscellaneous causes.

The extent of losses and the average age of death will be discussed separately for each autopsy classification.

Pneumonia was found to be the greatest cause of death, accounting for 169 (16%) of the lambs presented for autopsy. The pneumonia observed in the lambs was of the croupous or lobar type described by Marsh (1958).

One unusual case was observed in an 11-day-old lamb. A fully matured timothy head was found in the right bronchus (fig. 1). It is hard to understand how such a large foreign object could travel against the angle of the awns, past the larynx, down the trachea and into the right bronchus. Several newborn lambs presented for autopsy had a partial atelectasis of the lungs. It is speculated that this condition and the inability of weak lambs to expel amniotic fluid plays a part in the high incidence of pneumonia in young lambs. Inhalation of foreign objects, both large and small, appeared to be an additional contributing factor.

The average age at death of lambs dying with pneumonia was 15 days. Twenty percent of the lambs with pneumonia died between 3 and 4 days of age and 20% between 12 and 17 days of age. The other 60% were

fairly well distributed between ages of 5 and 40 days. This indicates that 4 and 15 days of age are critical periods.

No Visible Lesions. Lesions indicating the cause of death were not found

TABLE 2. AUTOPSY FINDINGS ON 1051 LAMBS FROM THE MONTANA AGRICULTURAL EXPERIMENT STATION RANGE FLOCK

Autopsy findings	Number of lambs	Percent of lambs born	Autopsy findings	Number of lambs	Percent of lambs born
Pneumonia	169	2.35	Miscellaneous—(total)	62	0.86
No visible lesions	167	2.32	Trauma	5	
Atelectasis (Stillborn)	151	2.09	Docking infection	5	
Starvation	146	2.03	Fractured ribs	5	
Dysentery	125	1.73	Fractured tibias	4	
Delayed parturition	53	0.73	Castration infection	3	
Enterotoxemia	48	0.66	Liver infarcts	3	
Prepartum death	39	0.54	Fractured skulls	2	
Liver rupture	29	0.40	Fractured metarsus	2	
Anomalies—(total)	27	0.37	Fractured femurs	2	
Diaphragmatocele	4		Fractured pelvis	2	
Megacolon	2		Blackleg	2	
Hydronephrosis	2		Arthritis	2	
Cardiac anomaly	2		Mechanical choke	2	
Leg anomaly	2		Coccidiosis	2	
Omphalocele	2		Hemorrhage, pyloric valve	2	
Contracted flexor tendons	1		Anasarca	1	
Megalo-ureters	1		Gastroenteritis	1	
Schistosomus reflexus	1		Cirrhosis, liver	1	
Mandibular anomaly	1		Pleuritis	1	
Hepatomegaly	1		Icterus	1	
Cranial anomaly	1		Intussusception, intestine	1	
Agnathia	1		Gastritis	1	
Aproctia	1		Myocardial abscesses	1	
Cervical anomaly	1		Duodenal torsion	1	
Lung anomaly	1		Cretin	1	
Epigastric hernia	1		Engorgement	1	
Alopecia	1		Adrenal neurofibroma	1	
Intestinal atresia	1		Pyemia	1	
Umbilical hemorrhage	12	0.16	Suffocation	1	
Navel infection	12	0.16	Tetanus	1	
Hemorrhagic enteritis	10	0.13	Pericarditis	1	
			Abdominal hemorrhage	1	
			Abomasitis	1	
			Ruptured cecum	1	
			Total	1051	14.7

in 167 lambs (15.8%) presented for autopsy. Milk was present in the digestive tract of these lambs. The average age at death of lambs in this group was 4.5 days. Seventy-six percent of the lambs in this classification died within the first 3 days of life.

Atelectasis (Stillborn) was the only autopsy finding in 151 (14.3%) of the lambs presented.

Starvation was determined to be the cause of death in 146 lambs (13.8%) examined at autopsy. The average age of the lambs that died from starvation was 6 days. Twenty-seven percent of the lambs were 3 days of age.

Dysentery observed in this study was of the type described by Marsh (1932). Under unsanitary conditions and during unfavorable weather, lamb dysentery can effect a very large proportion of newborn lambs. Even though the flock and lambing were managed under average conditions, lamb dysentery was observed in 125 (11.8%) of the lambs presented for autopsy. The average age at death was 3.8 days. Eighty-five percent of the

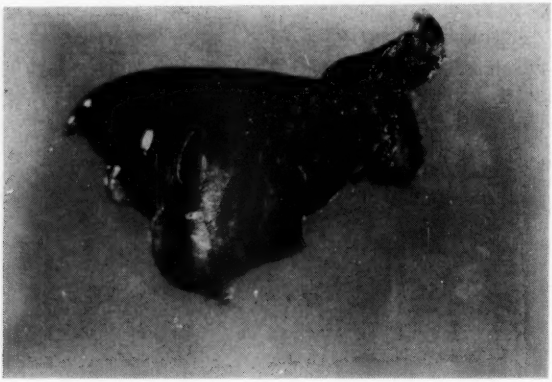

Figure 1. Timothy head in the right bronchus of an eleven-day-old lamb.

lambs dying were between 1 to 4 days of age. The true picture of dysentery loss is not available because during severe outbreaks sulfa drugs were administered to lambs affected.

Delayed Parturition was determined to be the cause of death of 53 lambs (5%).

Enterotoxemia. Forty-eight (5%) of the lambs presented for autopsy died from enterotoxemia. All cases of enterotoxemia in the very young lambs were confirmed by neutralization tests in mice. Autopsy findings in the young lambs were excessive pericardial fluid and endocardial hemorrhages. Hemorrhages or hyperemia of the small intestine mucosa was seldom observed. The finding of the "pulpy kidney" was inconstant.

Usually *Clostridium perfringens,* Type D, antiserum was administered to the lambs each year following the finding of several lambs with enterotoxemia at autopsy. Due to this treatment the true picture of enterotoxemia losses could not be obtained.

The average age at death of lambs with enterotoxemia was 12.6 days. One lamb was 1 day old. There appeared to be two most susceptible age groups. Forty-two percent of the lambs dying from enterotoxemia were from 1 to 4 days of age. Thirty percent died between 17 and 30 days of age.

Prepartum death was responsible for the loss of 39 lambs (3.7%) presented for autopsy.

Liver Rupture. One unexpected finding was that liver rupture caused the death of 29 (2.7%) of the lambs presented for autopsy. Examination

Figure 2. A lung anomaly attached to the dorsal surface of the left cardiac lobe of the lung from a newborn lamb. Note comparative size of the mass with the heart and the atelectatic lung.

revealed the abdominal cavity filled with blood. The source of the blood in the abdominal cavity was from a rupture in the capsule of the liver. The rupture usually extended vertically down the parietal surface of the liver from the area of attachment to the diaphragm. A large clot of blood could most always be found attached to the ruptured area.

The average age of lambs lost from liver rupture was 1.1 days. Sixty-five percent of the lambs died immediately following birth and 35% died within 24 hours. It is postulated that 65% of the livers ruptured during passage of the lamb through the birth canal. It is further postulated the other 35% were due to trauma after birth of the lamb, such as being stepped on by the ewe. Sixty-seven percent of the lambs with liver rupture were from 2- and 3-year-old ewes, further indicating the possibility of parturition trauma.

Anomalies. Twenty-seven (2.5%) of the lambs presented for autopsy were found to have 19 various anomalies. Sixty-one percent of the lambs

found with anomalies died within the first 24 hours after birth. The average age at death of this group was 3.8 days.

One unusual anomaly of the lung was found in a lamb that died immediately following birth. Autopsy revealed considerable amounts of subcutaneous fluid. The thoracic cavity was filled with a mass, 15 × 7.5 × 7.5 cm., attached to the dorsal portion of the left cardiac lobe of the lung, fig. 2. As a result the heart and lungs were crowded into a very small area in the thoracic cavity. The surface of the liver was uneven. The mass was attached to the lung by a capsule of firm, fibrous tissue that was continuous

Figure 3. Hemorrhage in the internal iliac and pelvic region of a newborn lamb. Classified as umbilical hemorrhage.

with the serosa of the lung. The lung parenchyma was not attached to the parenchyma of the mass.

It was the opinion of Marsh (1954) and Feldman (1954) that the mass was composed of cells predominately of mesodermal origin and was an accessory lobe of the lung that resulted from some prenatal mishap. Microscopic examination of the liver showed extreme congestion with some liver cell destruction.

Umbilical hemorrhage accounted for 12 (1.1%) of the lambs presented for autopsy. Autopsy would reveal massive hemorrhages under the peritoneum, in and around the internal iliac region of the abdominal cavity, fig. 3. The source of blood was from the ends of the umbilical arteries. It appeared that the umbilical arteries had been broken off inside the abdominal cavity, under the peritoneum, at or following birth of the lamb. It can be assumed that the ewe may have arisen upon delivery of the lamb, with the umbilical cord still attached, turned rapidly to lick the lamb resulting in the umbilical arteries being broken off inside the abdom-

inal cavity of the lamb. Lambers often pick up a lamb, immediately following delivery, pulling on the attached umbilical cord until it snaps in two. Perhaps these are factors that contribute to the incidence of umbilical hemorrhage.

The average age at death of the lambs with umbilical hemorrhage was 1.4 days. Seventy-five percent of the lambs died between 1 and 2 days of age, while 16% died within 24 hours after birth.

Navel Infection. Twelve lambs presented for autopsy (1.1%) were found to have died from navel infection. Autopsy findings included necrobacillosis of the liver, intervertebral abscesses and purulent arthritis.

Tincture of iodine was routinely applied to the umbilical cord stump of all newborn lambs. This practice reduced the incidence of navel infection

Figure 4. Cretinism in a newborn lamb.

to 0.16% of the 7191 lambs born. Severe losses have been observed in lambs born under shed lambing conditions of Montana in which tincture of iodine was not applied. The average age of death of lambs with navel infection was 24.7 days.

Hemorrhagic Enteritis. Ten lambs (0.9%) presented for autopsy were found to have an intense hemorrhagic enteritis. The average age at death was 6.2 days. Seventy percent of the lambs in this category died within 1 to 3 days of age.

Miscellaneous Findings. Sixty-two lambs (5.9%) presented for autopsy revealed 34 different findings which were placed in the miscellaneous classification. The average age at death of this group was 8.2 days. Bone fracture was the most common autopsy finding placed under miscellaneous findings.

Blackleg was found in one lamb that died at 3 days of age and one that died at 11 days of age. In both lambs the cervical muscles contained the typical blackleg lesion with its butyric acid smell. *Clostridium feseri* was isolated from each lesion.

Mechanical choke was found in two lambs caused by a 0.5-gram bolet

lodged in the larynx. Lambers had been treating the lambs for dysentery. Only one cretin was observed out of the 7191 lambs. It died at birth and presented a typical picture, fig. 4.

A neurofibroma of the adrenal gland was found in one lamb that died at 1 day of age. The left adrenal was 5 × 1.25 cm. in size. The right adrenal was normal in size. Microscopically the neoplasm was found to consist of dense fibrous connective tissue with many groups of large polygonal cells with pale nuclei and dark staining mucleoli of the nerve type.

A lamb that died at 10 days of age was found to have a ruptured cecum. Near the distal end of the cecum a round ulcerated area had penetrated the wall. The opening was 7.5 mm. in diameter. Newly formed fibrin and an extensive peritonitis extended out from the ruptured area.

The ages of the lambs examined at autopsy varied from 0 to 45 days. The average age at death of the 1051 lambs examined was 5.9 days. Fifty-six percent of the lambs died within the first three days of life. Seventy-three percent of the lambs died within the first five days of life. Moule (1954) reported that 57% of the lamb losses in Queensland, Australia, occurred within the first three days of life, agreeing very closely with the findings of this study. The study of lamb losses, therefore, entails a study of losses in the very young lamb.

Summary

During a three-year period, 7191 lambs were born to ewes in the Montana Agricultural Experiment Station range flocks. Twenty-three and one-half percent (1693) of the lambs died between birth and weaning. Sixty-two percent of the lambs dying were autopsied. Seventy-two and one-tenth percent (758) of the deaths were placed in five principal categories as a result of the autopsy findings. These major classifications were pneumonia, 16%; starvation, 13.8%; no visible lesions, 15.8%; stillbirths, 14.3% and dysentery, 11.8%. Other causes of death of significant importance were delayed parturition, prepartum death, liver rupture, enterotoxemia, hemorrhagic enteritis, umbilical hemorrhage, and navel infection. Liver rupture and umbilical hemorrhage were unexpected findings as causes of death in newborn lambs.

The average age at death of the 1051 lambs examined was 5.9 days. Fifty-six percent of the lambs died within the first 3 days of life and 73% within the first 5 days.

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INFLUENCE OF THREE DIFFERENT FEEDING LEVELS DURING GROWTH AND GESTATION ON REPRODUCTION, WEIGHT GAINS AND CARCASS QUALITY IN SWINE

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IT is a common practice in Wisconsin to limit the feed intake of growing pigs throughout most of the summer and then increase the level to a full feed as the new corn crop matures. The degree of feed limitation varies considerably depending upon the feed supply available on the farm. The effects of such a regimen on the economy of producing a market hog, the effects on carcass merit, and on the reproductive performance of gilts are unknown.

Merkel *et al.* (1958) have demonstrated that feeding a high fiber ration in dry lot increases the percentage lean cuts and decreases backfat thickness of pigs slaughtered at market weight. Haines *et al.* (1959) reported that limiting the energy intake to 50% of full feeding of gilts on pasture during growth and gestation reduced ovulation rate and embryonic mortality and increased the age of puberty. Embryo mortality during the entire gestation period was 10% greater for full-fed gilts than for limited-fed gilts. Other workers (Robertson *et al.*, 1951; Self *et al.*, 1955; Gossett and Sorensen, 1959) have reported an advantage in embryo survival for limited feeding in dry lot at 25 and 40 days of gestation.

In general, the studies cited have dealt only with traits in a limited period of the production cycle of swine without regard to concurrent or simultaneous effects on other economically important traits. The present study was designed to provide information on several different production traits simultaneously. Specifically, data have been obtained regarding the rate and cost of gains, carcass quality and the reproductive level of gilts when allowed different levels of feed intake on pasture.

Materials and Methods

Three lots were established for each of 3 years on 2 acres of alfalfa-brome-ladino pasture. A summary of stand counts of the vegetative cover is shown in table 1. Each lot was subdivided into two equal areas and designated as A and B. Area A in each case contained eight pigs and area B contained only four pigs as a means of altering the grazing intensity.

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TABLE 1. SUMMARY OF STAND COUNTS [a]

Season	Lot number	Alfalfa	Clover	Weeds
Spring	1	4.2	2.0	2.2
	2	4.7	1.7	2.3
	3	4.1	1.6	0.8
Midsummer	1	2.0	3.6	1.6
	2	2.7	2.7	1.5
	3	2.7	1.9	1.0
Fall	1	2.1	2.1	0.9
	2	2.6	3.2	0.2
	3	2.0	1.9	0.2

[a] Expressed as plants per square foot.

Lot 1 comprised an area of approximately one-third acre and the pigs were allowed to eat *ad libitum* the ration shown in table 2. Lot 2 totaled approximately two-thirds acre and the pigs were hand-fed the same ration as Lot 1 but at a rate estimated to be two-thirds the concurrent daily intake of the pigs in Lot 1. Lot 3 totaled about 1 acre and the pigs were hand-fed the same ration as those in Lots 1 and 2 at 50% the rate of those in Lot 2 (one-third the rate of Lot 1). The ration used in this study was the same for all three years and is shown in table 2. There was no estimate made of the nutritive value of the pasture for any of the three years.

The foundation animals consisted of 18 purebred Poland China and 18 Montana crossbred pigs ranging in weight from 27 to 69 lb. which were allotted at random into the six pasture lots from within breed groups. These pigs were started on pasture on May 18, 1955. During the second and third years the pigs were put on pasture on May 21.

TABLE 2. COMPOSITION OF RATIONS USED AT VARIOUS STAGES OF THE STUDY [a, b]

	Wean to pasture [c]			Pasture to market [d]
Stage and lot	1	2	3	All lots
Ingredients, %				
Corn	60	44	25	70
Oats	15	20	30	15
Ground alfalfa	10	25	35	..
Soybean oil meal (44%)	10	8	7	10
Meat and bone scraps (50%)	5	3	3	5
Trace mineral salt	0.5	0.5	0.5	0.5

[a] Zinc sulfate heptahydrate was added to all rations at the rate of 100 ppm.

[b] Antibiotic (Aureomycin) was added to all rations at the rate of 10 mg. per pound of ration until a lot averaged approximately 125 lb. live weight.

[c] These rations were self-fed in dry lot from the time each litter was weaned until the pigs went on pasture.

[d] This ration was fed to the three lots at the levels outlined in text and covers the period from the time the pigs went on pasture until removed for slaughter or the breeding herd.

The pigs were weighed at monthly intervals until they approached market weight. In cases where it seemed desirable, weights were then taken at bi-weekly intervals. The animals used to provide carcass information were removed from their pen and slaughtered at the first weigh date at which they averaged in excess of 200 lb. This procedure resulted in considerable variation in slaughter weight among the individuals within a lot. At the time that Lots 1 and 2 were marketed, the pigs in Lot 3 were considerably lighter each year than in either Lot 1 or Lot 2. For this reason, and to simulate the conditions on farms in the area, the pigs in Lot 3 were changed to a full-feed level at the time the last animals in Lot 2

TABLE 3. AVERAGE DAILY GAIN, FEED CONSUMED AND FEED EFFICIENCY BY YEAR AND FEED LEVEL GROUPS

Lot no.	Av. D. gain, lb.	Av. feed[b] consumed (daily), lb.	Feed[b] lb. gain	Total days on feed	Av. D. gain, lb.	Av. feed consumed (daily), lb.	Feed lb. gain	Total days on feed
	1955[a]				1956			
1	1.47	5.56	3.78	100	1.72	4.51	2.62	91
2	1.30	3.65	2.81	128	1.37	3.98	2.91	108
3 (Initial period)	1.02	2.02	1.98	128	1.03	2.45	2.38	122
(Full feeding period)	2.24	12.13	5.40	25	2.97	10.20	3.43	25
3—Overall	1.23	3.79	3.08	153	1.35	3.71	2.75	147
	1957				Combined total			
1	1.59	5.53	3.48	111	1.59	5.29	3.33	101
2	1.42	4.80	3.38	125	1.38	4.32	3.13	117
3 (Initial period)	1.03	2.66	2.58	124	1.03	2.46	2.39	125
(Full feeding period)	3.50	15.10	4.32	15	2.81	11.90	4.23	21
3—Overall	1.16	3.30	2.84	139	1.23	3.54	2.88	146

[a] Each mean for 1955 is an average of 7 animals; each mean in 1956 and 1957 represents 6 animals.
[b] The average daily consumption and the feed per lb. gain were derived from all pigs in the pen during a weight period.

were shipped to slaughter. The number of days on full feed necessary for the Lot-3 hogs to reach market weight was 26 days in 1955, 24 days in 1956, and 14 days in 1957. Separate records were kept on weight gains and feed consumption for this period as is shown in table 3.

Five or six gilts were selected from each lot to provide information on reproduction and to supply pigs for the following year. All the gilts saved from each lot were bred but only four were used for farrowing records. These four were selected so as to provide as much uniformity in litter ages between lots as possible. In all cases, the offspring were returned to the same lots and the same level of feed as their dams, thus the 1957 pasture season represented the third generation that had been maintained on the same feeding level. Gilts for breeding were selected on the basis of general appearance, meatiness, weight for age, general health and freedom from heritable defects.

The gilts saved from the foundation stock were bred to a purebred Berkshire boar in the fall of 1955 for farrowing in the spring of 1956.

Gilts from this first cross were bred to a purebred Hampshire boar. A purebred Spotted Poland China boar was used the third year. Only spring litters were produced and the farrowing season ranged from February 11 to April 2 during the three year period.

Gilts to be used for the breeding studies were separated from the rest of the animals at or before those scheduled for slaughter were removed. In 1955, they were separated on August 26 at an average weight of 172 lb. in Lot 1, 187 lb. in Lot 2 and 144 lb. in Lot 3. In 1956, separation of gilts in Lot 1 occurred on July 17 at an average weight of 194 lb.; Lot 2 was separated on July 30 and averaged 186 lb. and Lot 3 was separated on August 28 and averaged 145 lb. In 1957, the Lot 1 gilts were separated on September 10 and had an average weight of 216 lb.; Lots 2 and 3 were separated on September 24 at an average weight of 218 and 168 lb., respectively. Following separation, all breeding gilts were allowed an average of 4.5 to 5.0 lb. per head daily until 2–3 weeks prior to the beginning of breeding. At that time all gilts were placed on full feed for flushing until 3 to 4 days following breeding. The gilts were then returned to their original lots and allowed an average of 6.0, 4.5 and 3.0 lb. of ration per head daily in Lots 1, 2 and 3, respectively. Following breeding they were allowed to eat grass silage *ad libitum*, daily. Records of silage consumption were attempted in 1955 and it was estimated that Lot 1 gilts consumed an average of 2 lb. of grass silage per head per day; Lot 2, 5 lb. and Lot 3, 8 lb. Accurate estimates were difficult because of weather conditions, inadequate silage feeding facilities, and dehydration of the silage. Grass silage was also provided in 1956 and 1957, but estimates of consumption were not attempted in these two years.

Gilts were brought into the farrowing house 3 to 4 days prior to their anticipated farrowing date and self-fed a lactation ration. Each gilt was penned individually in a farrowing pen with access to an outside run. The pigs were treated for anemia with an iron pill at 4 to 5 days of age and usually again at 2 to 3 weeks of age. The pigs to be used to continue the studies during the following year were selected soon after weaning, confined to dry lot and given the ration for their respective lot as shown in table 2 until the pasture season began.

Analysis of variance was used to test for differences among treatment groups. Where there were significant differences, a multiple range test was used to determine where the difference existed (Duncan, 1955).

Results and Discussion

Dividing each lot into a subdivision (A and B) as a means of altering grazing intensity did not appear to have any influence on any of the management traits observed. Therefore, subdivisions A and B have been pooled and treated as a single lot. Adequate pasture was available at all

times in all lots and was not considered to be a limiting factor in any of these studies.

Average daily gain, daily feed consumed and feed efficiency calculated during the pasture period (pooled for the three years) was 1.59, 5.29, 3.33; 1.38, 4.32, 3.13; and 1.23, 3.54, 2.88 for the full-fed, two-thirds full-fed and one-third full-fed groups, respectively (table 3).

All of the pigs in this study had access to pasture. This prohibits a direct estimate of the value of pasture in feed savings. However, an estimate of the relative value of the pasture was obtained by comparing the feed requirements per pound of gain in the full-fed lot with each of the two limited-fed lots. The heaviest stocking rate for pigs on two-thirds full feed was 24 pigs per acre, whereas the heaviest rate for pigs on one-third full feed was 16 pigs per acre. Both of these rates could have been increased without damage to the pasture. The pigs gained an average of 170 lb. each while on pasture for a total gain per acre of 4080 lb. and 2720 lb. for the two lots, respectively. Compared to the feed conversion rate in the full-fed lot, there was a saving of 0.20 and 0.45 lb. of feed per pound of gain on the two-thirds and one-third levels, respectively, which resulted in a saving of 816 lb. and 1224 lb. of feed per acre for the two levels. Thus, if feed costs are estimated at $60 per ton, the pasture was worth $24.48 per acre more than for full feeding when the pigs were restricted to two-thirds of a full feed and $36.72 per acre more when they were restricted to one-third of a full feed. This is a saving of approximately $1.00 per pig in Lot 2 and $2.30 per pig in Lot 3. However, if the additional month to 6 weeks required for the pigs on the one-third feed level to reach market weight occurred on a declining market, a decrease of only $1.00 per cwt. in the value of the market hogs would be sufficient to nullify the savings on feed costs. Lot 2 required an average of 16 days longer to reach market weight than did Lot 1.

An initial analysis of the weight data for the hogs furnishing carcass information indicated highly significant slaughter weight differences existed among treatment groups and years. Therefore, all the data on carcass traits were corrected for weight differences by using the within treatment-year group regression for each trait involved.

Feeding level had a significant effect on average carcass backfat (tables 4 and 5) ($P<0.01$). Pigs from Lot 3 (one-third the nutrient intake of the full-fed pigs except as noted in materials and methods for the last part of the feeding period) had less average backfat at slaughter than either Lot 1 or Lot 2, (table 5; average of 1.52 vs. 1.72 and 1.73). Percent lean cuts was also different for the three feed levels ($P<0.01$). Carcasses from the one-third and two-thirds full-fed groups had a higher percentage of lean cuts than did the full-fed gilts (51.4 and 49.7 vs. 48.7) and the one-third full-fed group had a greater percent lean cut value than those on two thirds full feed (51.4 vs. 49.7). These data support the long established practice of restricting the feed intake and consequently growth rate to

result in a leaner carcass. Merkel *et al.* (1958) reported an increase in percentage of lean cuts for pigs confined to dry lot and fed TDN levels restricted to 69 and 62% as compared to pigs fed a control TDN level of 76%. Their study also showed a decrease in average backfat thickness for the restricted groups. In the present study there was a significant difference in carcass length and percentage of lean cuts among years ($P<0.01$). The average carcass length was greater in 1956 than in 1955 or 1957, but the 1956 carcasses had a thicker backfat and a lower percent lean cuts than the 1955 or 1957 carcasses ($P<0.05$). Loin eye area was

TABLE 4. ANALYSIS OF VARIANCE FOR REPRODUCTIVE DATA AND CARCASS CHARACTERISTICS

Source of variance	d.f.	Gilt wt. at farrowing	Pigs born	Pigs weaned	Birth weight	Weaning weight
Level of nutrition	2	39,594**	4.30	4.35	0.150	23.40
Year	2	4,810	9.75	8.15	1.000**	285.60**
L x Y	4	854	5.22	5.25	0.225	6.20
Error	27	1,459	5.89	5.22	0.078	19.93

		Carcass backfat	Carcass length	Loin eye area	Percent lean cuts
Level of nutrition	2	0.270**	0.40	0.11	31.45**
Year	2	0.095	2.65**	0.18	57.80**
L x Y	4	0.002	0.70	0.26	8.35
Error	45	0.031	0.50	0.38	4.95

* Significant at probability level of 0.05.
** Significant at probability level of 0.01.

not affected by level of nutrition or year. This latter observation suggests that loin eye area is more difficult to influence by altering management practices than is either length or percent lean cuts. The interaction of feed level and year was not significant for any carcass trait studied (table 4).

There was a significant weight difference among the feeding level groups at farrowing. Full-fed, two-thirds full-fed and one-third full-fed gilts averaged 480, 427, and 365 lb., respectively, at approximately 110 days gestation. These differences were all significantly different from each other and are not explained by litter size differences.

The average litter sizes of 7.7, 8.5 and 8.8 pigs farrowed alive for Lots 1, 2, and 3, respectively, did not differ statistically, nor did the averages of 7.3, 8.3, and 8.4 pigs weaned in the three lots. It has been demonstrated by Self *et al.* (1955) that increasing the feed level of limited-fed gilts for one estrual cycle will increase their ovulation rate to a level equal to that of gilts full-fed continuously. Zimmerman *et al.* (1957) have demonstrated that an increased feed intake for only 2 weeks prior to ovulation will increase the ovulation significantly over limited-fed gilts. In the present study all three lots were flushed (full-fed) for at least 2 weeks prior to

TABLE 5. LIVE WEIGHT, AVERAGE CARCASS BACKFAT, CARCASS LENGTH, LOIN EYE AREA, AND PERCENT LEAN CUTS BY YEAR AND FEED LEVEL GROUPS (CORRECTED FOR SLAUGHTER WEIGHT DIFFERENCES)

	1955[d]			1956[d]			1957[d]			Year averages			Feed-level averages		
Item	Full	2/3	1/3	Full	2/3	1/3	Full	2/3	1/3	1955	1956	1957	Full	2/3	1/3
Live weight at slaughter, lb.	231	223	229	221	195	222	239	222	217	228	212	226	230	213	223
Carcass backfat, in.	1.69	1.66	1.48	1.80	1.81	1.61	1.68	1.72	1.46	1.61	1.74	1.62	1.72	1.73	1.52[a]
Carcass length, in.	29.4	29.2	28.6	30.0	29.7	29.5	28.7	29.2	29.2	29.1	29.7[c]	29.1	29.4	29.4	29.1
Loin eye area, sq. in.	4.82	4.72	4.62	4.33	4.45	4.81	4.74	4.38	4.57	4.72	4.53	4.56	4.63	4.52	4.67
Percentage lean cuts	50.0	51.2	52.3	47.0	46.3	50.4	49.3	51.7	51.3	51.2	47.9[c]	50.8	48.7	49.7	51.4[b]

[a] One-third full-fed groups differ from two-thirds and full-fed ($P<0.05$).
[b] Percent lean cuts differ significantly from each other in all feed level groups.
[c] 1956 percent lean cuts and carcass length differ significantly from 1955 and 1957 ($P<0.01$).
[d] Each within feed level-year mean is an average of 6 animals.

TABLE 6. AVERAGE GILT WEIGHT AT FARROWING, PIGS BORN AND WEANED, BIRTH WEIGHT AND WEANING WEIGHT BY YEAR AND FEED LEVEL GROUPS

	1956[a]			1957[a]			1958[a]			Year averages			Feed-level averages		
Item	Full	2/3	1/3	Full	2/3	1/3	Full	2/3	1/3	1956	1957	1958	Full	2/3	1/3
Gilt weight at 110 day gest., lb.	465	424	380	515	445	374	460	413	341	423	445	405	480	427	365[b]
No. live pigs born	6.5	6.2	9.2	8.8	9.8	8.8	7.8	9.5	8.5	7.3	9.1	8.6	7.7	8.5	8.8
Average birth weight,[c] lb.	3.0	3.4	2.8	2.5	2.5	2.6	3.2	2.8	2.7	3.1	2.5	2.9	2.9	2.9	2.7
Average number pigs weaned	6.5	6.0	8.8	7.8	9.5	8.0	7.8	9.5	8.5	7.1	8.4	8.6	7.3	8.3	8.4
Average weaning weight,[c] lb.	31	30	26	26	26	25	35	36	34	29	25	35	31	30	28

[a] Each mean (within feed level-year) represents 4 gilts or litters.
[b] Gilt weight significantly different for each feed level. ($P<0.05$).
[c] Birth weight and weaning weight are not corrected for litter size.

breeding; therefore, any differences reflected in number of pigs farrowed alive are assumed to be due to differences in embryo survival rather than differences in ovulation rate.

The consistent failure in all three years of the heavier gilts in Lot 1 to perform as well as the average of the two limited-fed lots seems to indicate that obtaining larger and heavier gilts by higher levels of feed intake is not advantageous and may even be detrimental to reproductive efficiency. The 3-year average weaning weights for total litters is also in favor of the limited-fed lots; therefore, lactating ability among the groups did not appear, in general, to be positively associated with weight of the dam at farrowing. Hanson (1958) and Haines *et al.* (1959) also failed to find a significant difference in litter size between groups of gilts on full feed and gilts restricted to 50–70% of *ad libitum* feeding during the growing and gestating period. The latter workers reported daily gains of 0.4 lb. for the restricted groups of gilts and 1.0 lb. for the gilts fed *ad libitum*. These gains are considerably lower than those in the present study. Their full-fed gilts gained at approximately the same rate as the most severely restricted gilts (Lot 3) in the present study. Other workers (Robertson *et al.*, 1951; Self *et al.*, 1955; Haines *et al.*, 1959; Gossett and Sorensen, 1959) reported significant advantages in embryo survival rates to the 25th and 40th days of gestation for restricted feeding.

The average birth weights and weaning weights for pigs farrowed alive and weaned (uncorrected for litter size) were respectively, 2.9, 31; 2.9, 30; and 2.7, 28 lb. for the three feed levels (table 6). These differences were not significant. There was a significant difference in both birth weight and weaning weight due to year effects (tables 4 and 6).

The level of feeding and year interactions were not significant for any of the reproductive phenomena studied (table 4).

These studies are in agreement with previous reports that limited feeding during the growing period and during gestation is not detrimental to litter size. Although the difference was not statistically significant, the advantage of 0.8 pig and 1.1 pigs over the three-year period for the groups grown out on two-thirds and one-third of a full feed suggests a beneficial effect on litter size in addition to the saving in feed costs when the daily feed intake of gilts is restricted. The performance of the Lot-3 gilts suggests that when practiced on pasture, the restriction in feed intake during the early growing period can be rather severe without reducing the size of litter farrowed or without being detrimental to lactating ability.

Summary

During a three-year period 90 weanling pigs were grown out at three levels of feed intake on pasture to provide information on carcass characteristics and reproductive phenomena.

Average daily gain, daily feed consumed, and feed efficiency calculated

from the beginning of the pasture season to market weight (pooled for the three years) was 1.59, 5.29, 3.33; 1.38, 4.32, 3.13; and 1.23, 3.54, 2.88 for full-fed, two-thirds full-fed and one-third full-fed groups, respectively.

Carcass data were obtained on 54 of the pigs. Average carcass backfat and percent lean cuts were 1.72, 48.7; 1.73, 49.7; and 1.52, 51.4 for the full-fed, two-thirds full-fed and one-third full-fed lots, respectively. The differences for each trait were significantly different from each other, except for average carcass backfat on the full-fed and two-thirds full-fed groups. Loin eye area or carcass length was not significantly affected by level of feeding. Year had a significant effect on carcass length and percentage of lean cuts ($P<0.01$).

Reproductive traits (litter size, birth weight, weaning weight and number of pigs weaned) were studied in 36 litters. None of these traits was significantly affected by feeding level; however, year had a significant effect on birth weight and weaning weight ($P<0.01$). The average gilt weight at farrowing was 480, 427 and 365 lb. for full-fed, two-thirds full-fed and one-third full-fed ($P<0.01$).

Level of nutrition and year interactions were not significantly different for any carcass or reproductive trait studied.

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EFFECT OF STAGE OF MATURITY, DEHYDRATING VERSUS FIELD-CURING AND PELLETING ON ALFALFA HAY QUALITY AS MEASURED BY LAMB GAINS [1, 2]

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HOW stage of maturity and harvesting procedure affect the feeding value of alfalfa hay—measured by such criteria as weight gains or milk production—is not well established. Weather often interferes with a well-designed experiment, or results are inconclusive because hay harvested by various means has been obtained from different cuttings, different fields, or even different areas. In addition, the systems used in describing stage of maturity are very seldom accurately defined.

Weir *et al.* (1959) reviewed the literature on the influences of maturity on the yield, chemical composition, and digestibility of alfalfa. The Kansas Station (Salmon *et al.*, 1925) reported weight gains for steers fed alfalfa hay harvested at four maturity stages. Dawson *et al.* (1940), with adequately described stages of maturity, reported a decline in milk production as alfalfa advanced from 10% bloom to 100% bloom. Problems with rain and insect damage, however, were encountered in their work.

Shepherd *et al.* (1954) made an extensive study on harvesting and preserving alfalfa. Direct comparisons of dehydrated, barn-dried, and sun-cured hay indicated great differences in quality as measured by milk yields. Camburn *et al.* (1942, 1944) compared the composition and digestibility of artificially dried, ensiled, and sun-cured alfalfas, but did not state whether the hays so treated were from a single field; neither did they state the method of artificial drying.

The present experiments were designed primarily for study of the effect of stage of maturity on the feeding value of alfalfa. Factorial designs were used for study of interactions of harvesting methods (dehydrated and sun-cured) and/or methods of feeding (pelleted and chopped hay). An important aspect of the study was the relating of chemical and physical characteristics to the quality of hay. The final criteria of feeding value were the weight gains and feed consumption of growing lambs.

Experimental

Selected for forage production each year were uniform fields of alfalfa with little or no variation due to soil type, soil fertility, uniformity of stand, foreign plant contamination or insect infestation. Irrigation supplied

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[4] Department of Agronomy.

adequate water. Treatments were so superimposed on the field that replications ensured representative hay. However, sampling revealed no differences within the fields. The second cutting was used in all years except 1958, when both the second and fourth cuttings were used.

Stage of maturity was determined by hand-counting the number of stems in a certain stage. For example, 10% bloom means that 10% of the stems selected at random across the field had one or more blossoms. Height of stand was determined by measuring the height of the plants as they stood, taken at random in the field.

In three of the four years, changes in chemical composition were determined by taking samples from the field each day during the period from pre-bud through full-bloom. This was done by crossing the field, selecting at random a few plants at a time and collecting at mower height all the growth (including any regrowth) until the sample was about one kilogram. Each sample was dried overnight on a tray in a forced-draft oven at 70° C., and then ground for laboratory analysis.

In field-curing, the alfalfa was mowed, windrowed the same day (moisture content about 65%), sun-cured and baled at 20% moisture. Rain or insect damage did not occur. In dehydrating, the alfalfa was field-chopped directly and immediately dehydrated in a commercial drum-type drier.

The field-cured and dehydrated hays were fed as either chopped or pelleted hay. Chopped hay was passed through a 1-inch screen. Pelleted hay was ground through a fine screen (1/16- or 3/64-inch) and made into 3/8-inch pellets by a conventional pelleting machine.

Each year, during a pre-experimental period of three weeks, a uniform group of crossbred wethers was trained to use individual feeding stalls, wormed with phenothiazine, and vaccinated (Blue tongue and contagious ecthyma). The most uniform sheep were then assigned at random to the various treatments. Sheep were weighed only after 12 hours without water and 24 hours without feed.

The sheep were fed individually twice daily all the feed they would consume. No weigh-backs were allowed, so that the animals consumed the entire ration with no selection. Dry matter was determined weekly on a kilogram sample of feed from each treatment. At the end of the experiment these samples were composited into samples for laboratory analyses.

Lignin was determined by the method of Ellis *et al.* (1946), protein by the A.O.A.C. (1955) method and holocellulose by the method described by Wise *et al.* (1946). Fat on the sheep carcasses was determined by the method described by Garrett *et al.* (1959). Statistical procedures as described by Snedecor (1956) were used for regression, correlation, and analysis of variance and covariance.

Results and Discussion

Daily sampling and analysis of the stand of alfalfa (figures 1 and 2) indicated a gradual increase in lignin during the pre-bud and bud stages,

with the most marked change at the onset of flowering. Ten percent bloom seemed to approximate the time when the lignin curve leveled off, remaining relatively constant or increasing much more slowly. Results from different years agreed relatively well on this point even though date and physiological stage were not always in agreement. Weather differences between years, for example, would influence plant physiological age differently each year. Therefore, a physiological measure of maturity stage, such as flowering, is to be preferred to time intervals. Quantitatively, lignin

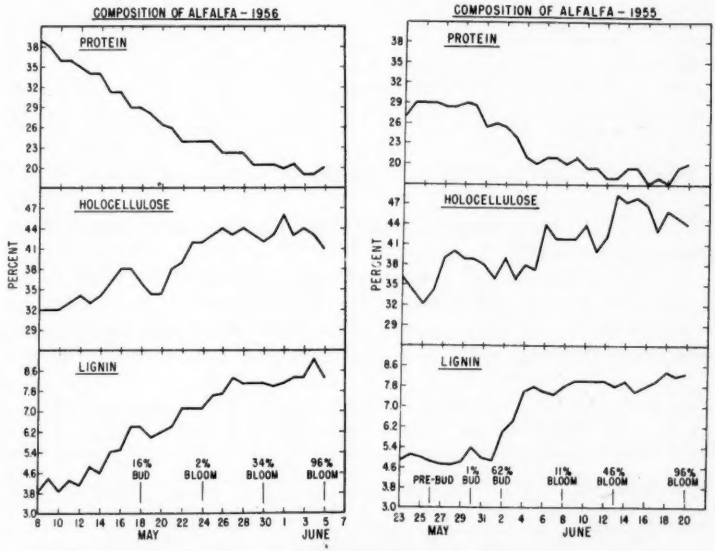

Figure 1. Changes in chemical composition with advancing maturity, 1955 and 1956.

contents of the 1955, 1956 and 1958 spring cuttings (the second in this area) agreed remarkably well. However, the lignin content of the August, 1958, cutting (the fourth cutting) leveled off at about the 10% bloom stage and was not as high as that of other cuttings. Nonetheless, it appears that physiological measures of maturity such as hand-counting stems in bud or blossom will indicate forage quality if lignin is the criterion.

As with oats (Meyer *et al.*, 1957), holocellulose followed lignin but was more irregular.

In general, protein content decreased in the stand, with a curve inverse to lignin. A change was marked at the onset of flowering, but not as marked as the change in lignin. The amount of protein in the stand showed remark-

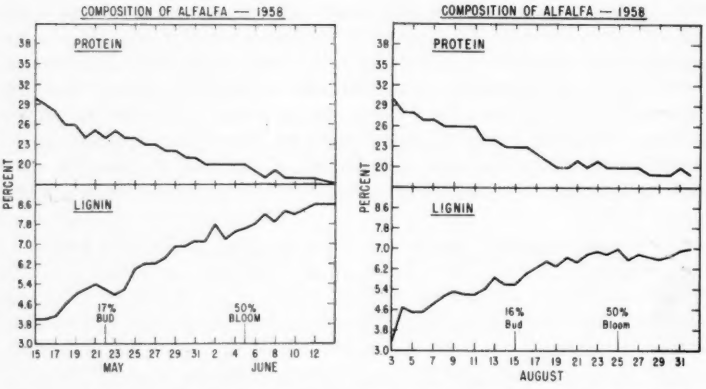

Figure 2. Changes in chemical composition with advancing maturity, 1958.

able agreement between years except that quantities were greater in the pre-bud stages in 1956.

In 1955 alfalfa was harvested at six stages of maturity (table 1) and dehydrated, ground and pelleted. The lignin content of the alfalfa was generally lower just before harvest than after dehydration and pelleting. Apparently there was a loss of plant components lower in lignin, such as

TABLE 1. RESPONSE OF SHEEP FED PELLETED DEHYDRATED ALFALFA HARVESTED AT VARIOUS MATURITY STAGES, 1955 [a]

Type of alfalfa	Pre-bud	1% bud	62% bud	11% bloom	46% bloom	96% bloom
Height of stand, in.	15	21	26	35	38	42
Composition:						
As harvested						
Lignin, %	4.8	5.4	5.9	7.8	7.8	8.3
Protein, %	29	27	25	20	18	19
As fed						
Lignin, %	5.3	6.4	6.6	8.2	8.2	8.3
Protein, %	31	27	25	21	19	17
Sheep data:						
No. per lot	6	6	6	6	6	6
Initial wt., lb.	70	69	73	71	66	69
Daily gain, lb.	0.31	0.26	0.22 [c]	0.13 [c]	0.30	0.23 [c]
Daily feed consumed, lb.	2.67	2.66	2.38	2.84	3.32	2.86
Adjusted daily gain, lb.	0.33	0.28 [c]	0.27 [c]	0.22 [b]	0.23 [b]	0.22 [b]
Gain per 100 lb. feed consumed, lb.	11.6	9.8	9.2	8.2	9.0	8.0

[a] All results reported on a dry matter basis; experimental period 72 days.
[b] Indicates a highly significant difference from the sheep fed the pre-bud hay.
[c] Indicates a significant difference from the sheep fed the pre-bud hay.

leaves and fine stems, during harvest. Protein content did not show these changes.

The daily gain unadjusted for feed intake showed some variation not related to lignin content or stage of maturity. Here gains were similar for pre-bud, 1% bud, and 46% bloom, but lower for the other maturity stages. However, by use of regression coefficients from the analysis of covariance, gain was adjusted statistically to equal feed consumption. Daily gains adjusted to a mean feed consumption showed that alfalfa was superior at pre-bud, followed by the bud stages. The bloom stages as measured in this experiment by adjusted daily gains were equivalent but much poorer in quality than the more immature stages.

TABLE 2. RESPONSE OF SHEEP FED ALFALFA HARVESTED AT VARIOUS MATURITY STAGES, 1956

Treatments	Pelleted				Chopped			
	18% bud	3% bloom	34% bloom	96% bloom	18% bud	3% bloom	34% bloom	96% bloom
	Dehydrated							
Lignin content of hay, %[a]	6.0	6.4	7.4	7.7	6.0	6.4	7.4	7.7
Protein content of hay, %[a]	26	26	21	20	26	26	21	20
No. of sheep per lot	5	5	5	5	5	5	5	5
Initial wt., lb.	54	60	60	62	60	60	64	62
Daily gain, lb.[c]	0.46	0.47	0.37[b]	0.38[b]	0.36	0.36	0.24[b]	0.24[b]
Daily feed consumed, lb.	3.6	3.9	3.9	3.8	3.1	3.6	3.2	3.0
Adjusted daily gain, lb.[c]	0.42	0.40	0.31[b]	0.32[b]	0.37	0.33	0.25[b]	0.26[b]
Gain per 100 lb. feed consumed, lb.	12.6	12.2	9.6	10.0	11.5	10.3	7.6	7.8
	Sun-Cured							
Lignin content of hay, %[a]	6.4	7.1	8.4	8.4	6.4	7.1	8.4	8.4
Protein content of hay, %[a]	24	24	20	20	24	24	20	20
No. of sheep per lot	5	5	5	5	5	5	5	5
Initial wt., lb.	57	61	61	65	66	59	57	56
Daily gain, lb.[c]	0.29	0.34	0.31	0.38	0.11	0.24	0.17	0.11
Daily feed consumed, lb.	3.1	3.5	3.4	4.1	2.0	2.8	2.4	2.1
Adjusted daily gain, lb.[c]	0.31	0.32	0.29	0.28	0.24	0.29	0.25	0.23
Gain per 100 lb. feed consumed, lb.	9.5	9.8	9.1	9.2	5.5	8.6	7.0	5.2

[a] The height of stand before harvesting was 23, 27, 35 and 38 inches for the 18% bud, 3% bloom, 34% bloom and 96% bloom, respectively, while the lignin was 5.5, 7.0, 8.0 and 8.3% and the protein 27, 26, 22 and 20%. Results reported on a dry matter basis; experimental period 56 days.

[b] Indicates a highly significant difference from the sheep fed the bud stage hay.

[c] The increase in gains of the sheep fed the dehydrated hay vs. the sun-cured hay was highly significant, while those fed the pelleted hays showed a highly significant increase in gains over those fed the chopped hay. There was a highly significant interaction of method of harvesting (dehydrating or sun-curing) and stage of maturity.

In 1956 (table 2) a factorial design utilized four maturity stages of alfalfa fed as dehydrated and sun-cured hay. Two methods of feeding were superimposed, and each hay was fed in the pelleted and chopped form. Lignin content was lower in dehydrated hay than in sun-cured hay, indicating that harvesting induced a loss of lower-lignified material during field-curing. Protein content confirmed the lignin results in an inverse manner. Here, however, the differences were not as striking.

The sheep response to stage of maturity when dehydrated alfalfa was fed was similar to that noted in 1955. As measured by weight gains (actual or adjusted to equal feed consumption), 18% bud and 3% bloom were superior to 34% and 96% bloom.

The differences between maturity stages were not as marked when the hay was sun-cured. In fact, the interaction of maturity stages and method of harvesting (dehydrating or sun-curing) was highly significant. Lignin and protein content would partially but not completely explain the response, since it appeared that the two immature stages lost relatively more valuable components in harvesting than did the bloom stages. The 18% bud alfalfa fed as chopped sun-cured hay was a special problem. Three percent of the dry matter was composed of a weed with sharp awns, foxtail barley (*Hordeum jubatum*). This influenced the feed consumption of the sheep in this lot but was not a problem for the animals fed the 18% bud hay in the other three forms.

At all maturity stages, dehydrated hay produced gains that were highly significantly greater than the gains of sheep fed sun-cured hay. This was true not only for the analysis of variance but also for the analysis of covariance, indicating that feed consumption would not completely explain the differences.

In all cases, a highly significant increase in daily gains occurred when the hay was ground and pelleted. The mean respective gains for all sheep fed chopped hay and pelleted hay were 0.23 and 0.38 lb., or, adjusted to equal feed consumption, 0.28 and 0.33 lb. These results indicate that feed consumption differences would explain most of the increase in gain. There was a tendency for the increase to be greatest with the hays of poorer quality.

Further investigations in 1957 were with sun-cured hays only, since maturity stage differences in the previous year were not as apparent with sun-cured hay. The results (table 3) indicate no differences in daily gain due to maturity stages. Inspection of the lignin content of the alfalfa before harvesting showed a much lower level in the 28% bud alfalfa. However, after harvest, lignin content was similar in all hays. This indicates a differential loss of materials low in lignin, such as leaves and stems. The greatest loss by far was in the bud stage hay.

A highly significant increase in daily gains occurred when pelleted alfalfa was compared to chopped alfalfa hay. In this case no significant difference was found when the analysis of covariance was used, indicating that greater feed consumption explained the greater gains from pelleted feed.

In 1958 the experimental design included alfalfa harvested at two stages of maturity, 13% bud and 50% bloom, dehydrated and sun-cured in May (2nd cutting) and August (4th cutting). All were ground and pelleted. Rain fell on the 17% bud alfalfa, sun-cured in May. The total was 0.63 inch. Consequently, a nearby field at the 13% bud stage was harvested and sun-cured three days later. This was used as a substitute. Nevertheless

the rain-damaged hay was included in the experiment because of the rare opportunity to compare the feeding value of essentially the same hay with and without rain damage. Table 4 reports the composition of these hays.

Bud stage hay in both months was lower in lignin and higher in protein than the 50% bloom alfalfa. The only marked difference between cuttings was that the August 50% bloom hay was lower in lignin than its counterpart harvested in May. Sun-curing resulted in a greater increase in lignin

TABLE 3. RESPONSE OF SHEEP FED SUN-CURED ALFALFA HARVESTED AT VARIOUS MATURITY STAGES, 1957[a]

	Chopped hay			Pelleted hay		
Type of alfalfa	28% bud	3% bloom	34% bloom	28% bud	3% bloom	34% bloom
Height of stand, in.	27	32	35	27	32	35
Composition:						
As harvested						
Lignin	5.6	7.0	7.8	5.6	7.0	7.8
Protein	28	24	22	28	24	22
As fed						
Lignin	7.7	7.6	8.2	7.7	7.6	8.2
Protein	26	25	22	27	25	22
Sheep data:						
No. per lot	6	6	6	6	6	6
Initial wt., lb.	65	67	66	68	64	65
Daily gain, lb.[b]	0.27	0.28	0.27	0.36	0.44	0.41
Daily feed consumed, lb.	2.6	2.7	2.6	3.3	3.4	3.5
Adjusted daily gain, lb.[c]	0.34	0.36	0.34	0.32	0.38	0.34
Gain per 100 lb. feed consumed, lb.	10.9	10.5	10.4	10.8	12.9	11.6

[a] All results reported on a dry matter basis; experimental period 56 days.
[b] No statistical difference between stages of maturity; however, there was a highly significant increase in daily gains due to pelleting.
[c] No statistical difference due to any treatment.

than did dehydrating the same alfalfa. Protein content was not differentially influenced by harvesting procedure.

Daily gains of the lambs (table 4) confirmed previous experiments with dehydrated alfalfa showing that bud stage alfalfa was superior to that in the flowering stage. Both actual gains and gains adjusted to equivalent feed consumption were higher for the sheep fed the 13% bud alfalfa than for those fed the 50% bloom alfalfa. Stage of maturity effects of similar magnitude were found with field-cured hay. The data obtained on the carcasses generally favored the bud stage hay, but the differences were not statistically significant.

Again, as in previous years, dehydrated hay was superior to sun-cured hay in evaluations with growing lambs.

TABLE 4. COMPARISON OF ALFALFA[a] HARVESTED IN MAY AND AUGUST, 1958, AT TWO STAGES OF MATURITY

Type of alfalfa	Height of stand	Lignin		Protein		No. of lambs	Initial wt.	Daily gain	Adjusted daily gain	Feed consumed daily	Gain per 100 lb. feed	Carcass data			
		As harvested	As fed	As harvested	As fed							Dressing %	Fat	Grade: No. choice	Grade: No. good
	in.	%	%	%	%		lb.	lb.	lb.	lb.	lb.	%	%		
Dehydrated:															
May:															
17% bud	25	5.5	6.9	27	25	6	74	0.44	0.45	3.42	13.0	51.0	23.0	6	..
50% bloom	38	7.6	8.5	19	19	6	76	0.36	0.38	3.35	10.6	49.6	23.6	2	4
August:															
16% bud	23	5.6	6.5	23	23	6	75	0.44	0.43	3.54	12.5	49.9	22.9	3	3
50% bloom	30	7.0	7.2	20	20	6	76	0.39	0.39	3.47	11.2	50.0	25.8	3	3
Sun-cured:															
May:															
13% bud	21	5.5	7.2	26	24	6	76	0.41	0.44	3.37	12.1	51.0	24.1	3	3
17% bud (rain-damaged)	25	5.5	7.9	27	26	6	73	0.35	0.38	3.31	10.7	49.1	23.4	2	4
50% bloom	38	7.6	8.8	19	20	6	78	0.32	0.29	3.68	8.8	47.8	23.2	2	4
August:															
16% bud	23	5.6	7.1	23	22	6	74	0.41	0.39	3.58	11.5	49.4	25.2	3	3
50% bloom	30	7.0	7.9	20	19	6	75	0.35	0.35	3.49	10.1	49.2	24.4	1	5
Summated means:[b]															
17% bud	24	5.6	6.9	25	24	24	75	0.43	0.43	3.48	12.3	50.3	23.8	15	9
50% bloom	34	7.3	8.1	20	20	24	76	0.36[c]	0.35[c]	3.50	10.2	49.2	24.2	8	16
Dehydrated	29	6.4	7.3	22	22	24	75	0.41	0.41	3.44	11.8	50.1	23.8	14	10
Sun-cured	29	6.4	7.7	22	21	24	76	0.37[d]	0.37[c]	3.53	10.6	49.4	24.2	9	15
May	32	6.6	7.8	23	22	24	76	0.38	0.39	3.46	11.1	49.9	23.5	13	11
August	26	6.3	7.2	22	21	24	75	0.40	0.39	3.52	11.3	49.6	24.6	10	14

[a] All results reported on a dry matter basis; experimental period 56 days.
[b] Not including the rain-damaged bud alfalfa in May.
[c] A statistically highly significant difference.
[d] A statistically significant difference.

The quality of alfalfa was not greatly influenced by season; the overall comparison of the hays harvested at the same maturity stages in May and August revealed only small differences.

Rain (0.63 inch) resulted in an increase in lignin and protein. Lambs fed this hay gained less than lambs fed either the dehydrated or field-cured hay. Interestingly enough, the bud stage hay damaged by rain produced greater gains than did the 50% bloom harvested in the usual manner.

It should be clearly understood that this study of alfalfa was on energy effects rather than protein, because the protein content of the hays was always adequate for growing lambs (Pope *et al.*, 1957).

From a consideration of the changes in lignin content with advancing maturity and the gains of lambs fed hay harvested at different stages of maturity, it appears that the 10% bloom stage was the critical turning point in feeding value. After 10% bloom the increase in lignin or decrease in daily gains of lambs fed this hay was not as great as that found between the bud and bloom stages. From lamb response, hay harvested at about the 10% bloom stage sometimes resembled bud stage hays and at other times resembled the more advanced bloom stages. Therefore, from a quality standpoint rather than yield and stand survival, alfalfa should be harvested before 10% of the stems have blossomed. A consideration of yield and stand survival reported by Weir *et al.* (1959) would indicate that 10% of the stems in blossom would be the recommended stage for harvesting.

Differences were always found between bud and bloom stages when alfalfa was dehydrated. Field-cured alfalfa did not always show difference between the various maturity stages. An inspection of the lignin content seemed to reveal a differential leaf loss because, with field-curing, lignin increased more markedly from the preharvest content in bud-stage hays than in bloom stage hays. This seems reasonable, since bud alfalfa has a greater percentage of leaf. In any case, alfalfa to be sun-cured should be harvested at the most immature stages commensurate with yield.

Of the two constituents, lignin and protein, lignin more often indicated quality as measured by lamb gains. The weighted average of the correlations of adjusted daily gains with lignin content was —.94, and with protein content it was 0.85. Both of the correlations are high. Lignin or other fiber fractions closely following lignin changes are to be preferred to protein for indicating the quality of alfalfa for energy. First, lignin itself has a direct effect on cellulose utilization. Second, in cases of rain damage, both lignin and protein increase while soluble constituents are leached. Since protein was positively correlated with measures of energy value and since protein was increased by rain damage, protein as a quality indicator in such case gave aberrant results.

A further search for some physical measure of quality revealed that height of stand, irrespective of maturity stage, year, or cutting, was correlated with lignin content. The regression of height and lignin content at harvesting was highly significant (figure 3). This was also true for

height and protein content. Since the results show a very high correlation between lignin content and adjusted daily gains, height appears to be a good indication of the time to harvest alfalfa in this area for the quality desired. Of course, harvesting procedures have a further influence that would be indicated not by height of stand, but by lignin (this paper) or crude fiber (Meyer and Lofgreen, 1956). Certainly, the relation of height of stand to alfalfa quality warrants further consideration and investigation.

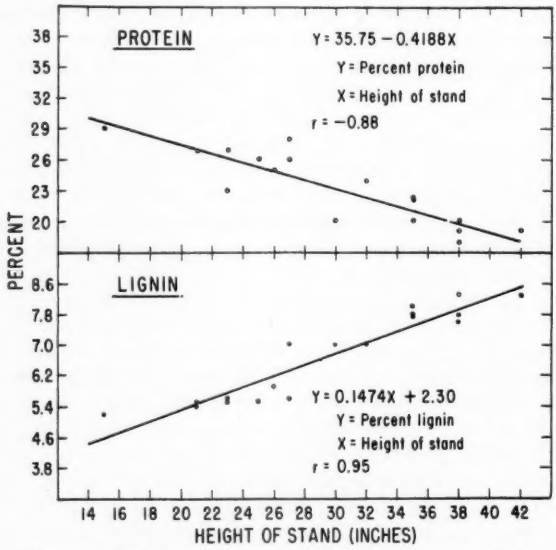

Figure 3. Relationship of pre-harvest lignin and protein content to height of stand.

The pelleted dehydrated alfalfa fed in 1955 was fed to a group of lambs randomly assigned to this experiment and to an investigation of the influence of stage of maturity of oat hay on its feeding value (Meyer *et al.*, 1956). These two hays were fed at the same time under the same conditions and were prepared in the same manner and by the same machines (harvesting, dehydrating, and pelleting). A direct comparison between the experiments is therefore valid. All stages of the alfalfa hay—from most immature to most mature—produced greater gains than any of the oat hays, even though the lignin content of some of the oat hays was lower. The regression of adjusted daily gain (Y) on lignin content (X) of oat hay was: $Y=0.35-0.0251X$, whereas the equation for alfalfa was: $Y=0.51-0.0344X$. These equations differ and add evidence for the statements of Meyer and Lofgreen (1956) that lignin should be used as an indication

of quality only within a single plant species or with plants having a similar site and progress of lignification.

The same alfalfa that was fed to the lambs in 1956 was also fed to swine (Heitman and Meyer, 1959). The pigs did not respond to differences in maturity that gave differences in weight gains in lambs. An explanation would be that lignification mainly affects cellulose utilization and that pigs lack a lignin response because they do not readily utilize cellulose. This comparison of swine and sheep indicates that lignin does not affect the energy nutrients available to swine. The evidence indicates that lignification influences hay quality primarily in cellulose availability to ruminants.

Summary

Results are reported of a four-year study on the influence of stage of maturity on the value of alfalfa as an energy source for sheep. Factorial designs were used for study of interactions of harvesting method (dehydrated and sun-cured) and/or method of feeding (pelleted or chopped hay). Another aspect was the relating of chemical and physical characteristics to hay quality. Weight gains and feed consumption of individually fed growing lambs were used to assess feeding value, which is primarily a reflection of energy value for ruminants since protein was not a limiting factor in alfalfa.

From a consideration of the changes in lignin content and the gains of the lambs fed hay harvested at different stages of maturity, the critical turning point in feeding value appears to be when 10% of the stems have one or more blossoms. After 10% bloom the feeding value did not change as markedly as between earlier maturity stages. Differences between bud and bloom stages were always found when alfalfa was dehydrated. Field-cured alfalfa did not always show this difference, because sometimes a relatively greater increase in lignin occurred as a result of harvesting loss for the bud-stage alfalfa compared to the bloom-stage alfalfa. No change in quality was observed between 30 and 100% bloom.

Dehydrated alfalfa was superior to field-cured alfalfa as an energy source in all cases. Pelleted alfalfa in all trials gave greater daily gains than chopped.

The respective correlations of lignin and protein content with adjusted daily gain (equal feed consumption) were —.94 and 0.85. Height of stand was very closely correlated with lignin and protein content before harvest, irrespective of year, cutting, or stage of maturity. This suggests that height of stand could be used as an indication of alfalfa quality when selecting a harvest date in this area.

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OVULATION RATE IN SWINE AS AFFECTED BY INCREASED ENERGY INTAKE JUST PRIOR TO OVULATION[1]

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HIGH plane feeding over a long period of time has been found to increase ovulation rate and decrease early embryo survival rate in the gilt as compared to low plane feeding (Robertson *et al.*, 1951; Christian and Nofziger, 1952; Self *et al.*, 1955; Gossett and Sorensen, 1959; Haines *et al.*, 1959; Zimmerman, 1959). Self *et al.* (1955) and Zimmerman (1959) have shown, in addition, that increasing the level of feeding for only 2 or 3 weeks prior to breeding (flushing) produces approximately the same ovulation rates as feeding a high plane for an extended period of time. The former workers (Self *et al.*, 1955) found that the embryo survival rate of flushed gilts tended to approach that of gilts fed continuously on the low plane of nutrition. The flushing experiments that have been carried out with swine either have provided increased levels of all nutrients or have attempted to provide an increased level of energy, only. In the latter case it has been necessary to alter the proportions of certain feedstuffs in the rations which in itself causes differences between the rations other than level of energy.

In the present investigation an attempt was made to determine the minimal flushing interval required to stimulate increased ovulation rate in gilts and to determine more directly whether the stimulaing influence of flushing on ovulation rate is attributable to increased energy intake *per se*.

Experimental Procedure

Study I. Thirty-two Chester White-Poland China and 16 Chester White gilts from the 1956 fall pig crop were used. The energy intake of all gilts was restricted to approximately 75% of a full feed from 3 months of age until puberty by self-feeding the 13.3% fiber ration outlined by Waldorf *et al.* (1958). Gilts of each breeding group were randomly assigned to a control (non-flushed) group and three flushed groups as they attained puberty. Control gilts were continued on the energy-restricted ration during their first estrual cycle. Flushed gilts were self-fed a low fiber, 5.9%, ration (Waldorf *et al.*, 1958) that was comparable to the high fiber ration in all nutrients other than energy, from day-16, day-12, or day-8 of their first

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estrual cycle to second estrus. This design allowed flushing intervals of approximately 6, 10 and 14 days.

All but a few of the gilts were penned individually on the day puberty was attained. Individual feed consumption was determined on the control gilts during their first estrual cycle and on the flushed gilts during the various flushing periods. Weight and backfat thickness were determined at the beginning and end of the flushing period. The gilts received the high fiber ration after exhibiting their second estrus. They were slaughtered 3 to 5 days after their second heat was first observed. Counts were made of the numbers of corpora albicantia and newly formed corpora lutea, and the difference was used as the basis for comparison.

TABLE 1. BASAL RATIONS USED IN STUDY II

Ration	1[a]	2[b]
Components, lb.		
Corn	515	415
Oats	250	250
Soybean meal (44%)	90	134
Meat scraps (50%)	90	140
Alfalfa leaf meal (17%)	50	50
Trace mineralized salt	5.0	5.0
Antibiotic mixture	1.0	1.0
Vitamin premix[c]	...	6.0
Zinc sulfate·$7H_2O$	0.5	0.5
Total	1001.5	1001.5

[a] Fed at the rate of 2½% of body weight per day during the second estrual cycle in experiment 1 and after gilts averaged 200 lb. in experiment 2, except that vitamins were added in expreiment 2.

[b] Fed at the rate of 2½% of body weight per day from approximately five months of age until gilts averaged approximately 200 lb. in experiment 2.

[c] Composed of 25 lb. soybean meal, 1 lb. irradiated yeast, 1 lb. riboflavin (4 gm. B_2/lb.) and 0.4 lb. pantothenic acid (32 gm./lb.).

Study II. This study consisted of two experiments conducted to determine whether or not the stimulating effect of flushing on ovulation rate was attributable to increased energy intake *per se*. In the first experiment the energy intake of 20 Chester White gilts from the 1957 fall pig crop was restricted to 60–75% of a full feed from 154 days of age until their first estrus following puberal estrus, the high fiber rations (14.2% and 18.0% fiber) as reported by Waldorf *et al.* (1958) being fed. The gilts were then randomly assigned to two experimental groups (flushed and non-flushed) in equal numbers and were hand-fed a basal ration (ration 1, table 1) twice daily at the rate of 2½% of lot-average body weight per day. Beginning on day-8 of their second estrual cycle, gilts were fed individually at the rate of 2½% of individual body weight, daily. Flushed gilts were fed glucose (mixed with basal), in addition, at the rate of 1% of individual body weight per day during the flushing period (day-8 of second estrual cycle to slaughter, 3 to 4 days following third estrus).

Blood samples for sugar determination were taken immediately before (14–16 hr. after previous feeding) and 1 and 2 hours after the morning feeding on day-9 of the glucose-feeding period. The blood samples were obtained from the anterior vena cava and were analyzed for sugar within 24 hours after collection. The method of Folin and Wu (1919) was used to prepare the protein-free blood filtrate and the concentration of sugar was determined by the Folin-Wu copper reduction method (1929). Gilts were slaughtered 3–5 days following third estrus and counts were made of the number of newly formed corpora lutea.

In the second experiment the energy intake of 32 Chester White gilts from the 1958 fall pig crop was restricted to approximately 70–75% of a full feed from 3 months until 5 months of age by self-feeding the 14.2% fiber ration outlined by Waldorf *et al.* (1958). From 5 months of age until day-8 of their first estrual cycle gilts were limited in energy intake by hand-feeding a basal ration (rations 1 and 2, table 1) at the rate of 2½% of lot-average body weight per day. The basal ration was designed to provide the minimal requirements of all nutrients other than energy in the restricted amounts fed. Gilts were randomly assigned to a control (non-flushed) and three flushed groups in equal numbers as they attained puberty. All gilts were individually hand-fed the basal ration at 2½% of individual body weight daily during the experimental period (day-8 of first estrual cycle to second estrus). One of the flushed groups was fed glucose and the other two groups received lard, in addition to the basal, during the flushing period. Glucose was fed at the rate of 1% of individual body weight per day and lard at the rate of 0.44% (low fat) and 0.66% (high fat) of individual body weight per day. After exhibiting their second estrus, gilts were group hand-fed the basal until slaughter 3–5 days later. At postmortem, counts of the numbers of corpora albicantia and newly formed corpora lutea were made and increase in ovulation rate from first to second heat determined.

Preflush and postflush weights were taken on the gilts in each experiment. Weight was also taken on each gilt 1 week after the flushing period was begun so that feed allowance could be adjusted for change in body weight. In each experiment of this investigation, daily heat checks with vasectomized boars were begun when the earliest born gilt in an experiment reached 5 months of age and were stopped when the experiment terminated.

Analysis of variance in these studies was done by the method of weighted means (Snedecor, 1956). The multiple range test (Duncan, 1955) was used to establish the significance of the differences between the subgroups. Simple correlations were calculated by pooling the sums of squares and cross-products from the different subgroups. Before pooling, however, a test for heterogeneity of regression using subgroup sums of squares and cross-products was made.

Results

Study I. The average lengths of the flushing intervals attained in this study closely approached those outlined in the experimental design. The actual intervals (averaged over both breeding groups) were 5.7, 9.0 and 13.8 days for the day-16, day-12 and day-8 groups, respectively.

Increase in ovulation rate from first to second heat was the characteristic studied to determine the effect of length of flushing interval on ovulation. The average increases in ovulation rate are shown for the various subgroups in table 2. The overall effect due to flushing was highly significant

TABLE 2. INCREASE IN OVULATION RATE FROM FIRST TO SECOND HEAT AS AFFECTED BY LENGTH OF THE FLUSHING PERIOD

Day of estrual cycle flushing was started	Length of[a] flushing period, days	Crossbred[b] No. C.L.				Chester White No. C.L.				Both breeds
		No. gilts	1st heat	2nd heat	Diff.	No. gilts	1st heat	2nd heat	Diff.	Diff.[c]
Control (unflushed)	0	8	9.4	10.8	1.4	4	11.0	12.5	1.5	1.4
Day-16	5.7	7	8.7	11.3	2.6	4	11.0	14.2	3.2	2.8
Day-12	9.0	8	8.9	11.4	2.5	4	11.5	16.0	4.5	3.2
Day-8	13.8	8	8.3	11.9	3.6	4	11.0	15.5	4.5	3.9

[a] Mean length of flushing period averaged over both breeding groups.
[b] Chester White X Poland China.
[c] Test of significance:
Day-12 or day-8 vs. control ($P<0.01$).
Day-16 vs. control ($P<0.07$).
Differences between the flushed groups were not significant.

but there was not a significant difference between the breeding groups or any evidence of an interaction between breeding group and flushing interval. The data for the two breeding groups were combined and further analysis was made with the multiple range test. Flushing for only 6 days stimulated a greater increase in ovulation rate than occurred normally in control gilts as a result of increase in sexual age from first to second heat (2.8 vs. 1.4 ova, $P<0.07$). The mean increases in ovulation rate of the flushed groups did not differ significantly from one another but there was a tendency for the ovulation response to increase with greater length of the flushing period.

An attempt was made to determine factors working within the subgroups which might have caused individual variation in increase in ovulation rate from first to second heat. Preflush weight and backfat thickness were used as measures of the way individuals had grown prior to flushing. Average daily gain and average daily feed consumption of the gilts during the flushing period were used as indications of the nutritive state of the gilts at the time of ovulation. The simple correlation between average daily feed consumption and increase in ovulation rate was the only association found to approach significance ($r=0.32$, $P=0.05—0.1$).

Study II. Gilts in experiment 1 that were fed glucose in addition to a basal ration for approximately 2 weeks prior to ovulation gained more rapidly and shed a greater number of ova than gilts receiving the basal ration only (table 3). Adjustment of ovulation rate for the within-group regression of ovulation rate on average daily gain did not remove the significance of the difference between the flushed and unflushed groups.

Increases in blood sugar level 1 and 2 hours after feeding were greater in the glucose-fed gilts than in the basal-fed controls (9.4 and 9.5 mg. % differences at 1 and 2 hours, respectively) but there was no indication of a difference in the fasting sugar levels (table 3).

TABLE 3. AVERAGE DAILY GAIN, AVERAGE NUMBER OF CORPORA LUTEA AND BLOOD SUGAR LEVEL AS AFFECTED BY FLUSHING WITH PURE ENERGY SOURCES

	Experiment 1						Experiment 2			
				Blood sugar, mg. %[e]						
					Increases after feeding					
Ration provided	No. gilts	Av. da. gain	No. C.L. 3rd heat	Level before feeding	1 hr.	2 hr.	No. gilts	Av. da. gain	No. C.L. 2nd heat	Increase[f] 1st to 2nd
Basal[a]	10	1.0	9.7	58.9	—.2	—2.0	8	1.0	9.8	1.5
Basal[a]+glucose[b]	10	1.6	11.8	56.5	9.2	7.5	8	1.5	10.6	1.8
Difference		.6**	2.1**		9.4	9.5				
Basal[a]+high fat[d]							7	1.7	11.7	3.0
Basal[a]+high fat[d]							8	1.9	13.9	5.1

[a] Rations (table 1) hand-fed at rate of 2½% of individual body weight per day during the experimental period (day-8 of estrual cycle to estrus or to slaughter 3–5 days after estrus).

[b] Glucose (mixed with basal) hand-fed at rate of 1% of individual body weight per day in addition to the basal ration during the experimental period.

[c] Lard (mixed with basal) hand-fed at rate of 0.44% of individual body weight per day in addition to the basal ration during the experimental period.

[d] Lard (mixed with basal) hand-fed at rate of 0.66% of individual body weight per day in addition to the basal ration during the experimental period.

[e] Blood sugar levels were determined on day-9 of the experimental period.

[f] Test of significance: 5.1 vs. 1.5 and 1.8, $P<0.05$; 5.1 vs. 3.0, $P=0.05-0.01$. Other differences were not significant.

** $P<0.01$.

In experiment 2, it was possible to study the effect of glucose and lard feeding on increase in ovulation rate from first to second heat. The results are summarized in table 3. All of the flushed groups gained significantly more rapidly than the unflushed group. The average daily gains of the flushed groups did not differ significantly from one another but tended to be greater on the high fat diet than on the lower energy diets. Only the high fat gilts produced a significantly greater increase in ovulation rate than occurred normally in control gilts as a result of increase in sexual age. The average increase in ovulation rate of the glucose-fed gilts was slightly greater than the increase of the unflushed gilts and significantly less than the mean increase of the high fat gilts. Lard-fed gilts receiving the same caloric intake as the glucose-fed gilts (low fat group) also failed

to show a significant advantage in ovulation increase over the unflushed controls. The difference between the average ovulation increases of the low fat and high fat gilts only approached significance (3.0 vs. 5.1 ova, P=0.05—0.1). When a comparison was made between the second heat ovulation rates of the various groups the same group differences were found. However, the mean ovulation rates showed more of a tendency for a flushing effect than the increases in ovulation rate from first to second heat.

Discussion

The results of these studies confirm and extend the findings of Self *et al.* (1955) and Zimmerman (1959). Ovulation rate in swine can be stimulated by increasing the nutrient intake for only a short interval of time before ovulation. It appears that flushing intervals as short as 6 days prior to ovulation will increase ovulation response but that some further increase may be obtained by flushing to 14 days. Whether or not short flushing periods such as those used in study I have a detrimental effect on embryo survival rate remains to be determined.

The addition of pure energy sources to a basal ration, which provided the minimum daily requirements of nutrients other than energy and supported moderate gain in body weight during a 14 day flushing period, was found to produce increased ovulation response. Studies are now needed on the energy requirements for maximal ovulation rate and whether or not an optimum protein-energy ratio is required for maximal ovulation response.

From the findings of these studies it appears that the energy intake during the time of follicular development has an important influence on ovulation rate in the gilt. The mechanism by which increased energy intake stimulates greater ovulation response is yet to be determined, e.g., increased gonadotrophin secretion or increased effectiveness of a given amount of gonadotrophin.

Summary

Thirty-two Chester White-Poland China and 16 Chester White gilts were used in a study to determine the minimal flushing interval required to stimulate increased ovulation rate. Fifty-one Chester White gilts were used in two other experiments to demonstrate the effect of increased energy intake, only, on ovulation rate.

Flushing for intervals of approximately 6, 10 or 14 days produced greater increases in ovulation rate from one estrual period to the next than occurred normally in unflushed gilts as a result of one estrual cycle increase in sexual age (increases of 2.8, 3.2 and 3.9 ova, respectively vs. an increase of 1.5 ova for unflushed gilts). There was a tendency for ovulation response to increase with greater length of the flushing period.

Gilts fed glucose in addition to a basal ration for approximately 2 weeks

prior to ovulation were found to shed a greater number of ova than gilts receiving only the basal ration (2.1 and 0.8 more ova in two different experiments, respectively). In the second experiment, gilts receiving a similar caloric intake furnished by lard were found to produce 1.9 more ova than the basal-fed gilts. The greatest response was obtained, however, when gilts were fed lard at approximately 150% of the caloric intake of those fed glucose—exceeding the ovulation rate of control gilts by 4.1 ova and the glucose and low fat gilts by 3.3 and 2.2 ova, respectively.

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THE RELATION OF FACE COVERING TO FLEECE WEIGHT, BODY WEIGHT AND KID PRODUCTION OF ANGORA DOES

MAURICE SHELTON [1]

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FOR many years, breeders of Angora goats have practiced visual selection, utilizing completeness of covering, including the face, as a means of obtaining maximum mohair production. Reports by Terrill (1941) and Shelton and Carpenter (1957) have shown that an excessive covering on the face of sheep may be detrimental to most efficient production. No reports are available concerning the influence of face covering on the performance of Angora goats, and the present study was undertaken to fulfill this need.

Materials and Methods

A small flock of registered Angora goats has been maintained on the Sonora Station (Texas Agricultural Experiment Station, Substation 14, Sonora) since 1918. The management of the flock and the type of data collected were discussed by Jones *et al.* (1935). The present report is based on a study of data collected on this flock between 1918 and 1946. This station is located in Sutton and Edwards County in the heart of the concentrated sheep and goat producing area of the Edwards Plateau. Within the limitations imposed in collecting the necessary records, the flock was managed in a manner similar to range flocks of the area. They were grazed year-long on range land partially covered by brush, and given a minimum amount of supplemental feed. This, in addition to the fact that in selection considerable emphasis was placed on mohair quality, provides a partial explanation for the rather low mohair weights in the present report as compared to current standards.

At each spring shearing, all does in the flock were scored or classified for hair covering on the face and belly. Data were also collected on staple length, fleece weight, fiber diameter, body weight after shearing, and kid production. In the period 1918 to 1933 three classifications were used for face covering, and these may be described as open (1), medium (2) and covered (3). In the period 1933 to 1946 four score units known as open (0), light (1), medium (2) and covered (3) were used. This inconsistency makes it necessary to analyze some of the data separately for the two periods. The scores utilized in the latter period are illustrated in figure 1.

[1] The author acknowledges the contribution of J. M. Jones, B. L. Warwick, S. P. Davis, O. L. Carpenter, R. E. Patterson, Fred Campbell and the late W. H. Dameron, all of whom at one time assisted in collecting or tabulating some of the data on which this report is based.

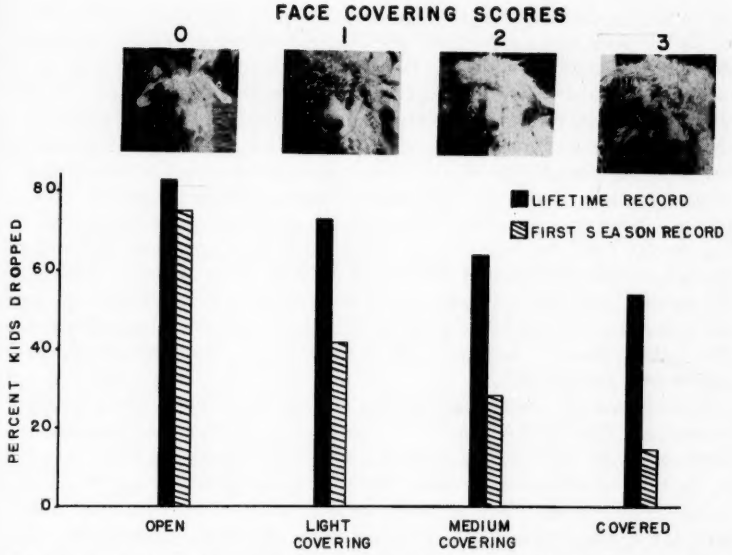

Figure 1. Face covering scores as related to kid production of Angora does (1933–46).

Results and Discussion

Correlation coefficients of face covering with other traits at one year of age (first spring shearing) are shown in table 1. Since these values were calculated on a within-year and sex basis, the disparity in method of scoring does not affect the correlation values. Lush and Jones (1924) have shown that records collected at the first fall shearing have a relatively low relationship to later performance. For this reason, records collected at this age were not utilized in the present report. The data in table 1 show face cover-

TABLE 1. CORRELATION OF FACE COVERING WITH OTHER CHARACTERISTICS AT ONE YEAR OF AGE CALCULATED ON WITHIN YEAR AND SEX BASIS (n=1117)

Character	Correlation coefficient
Belly covering	0.175**
Fiber diameter	—.133**
Fleece weight	0.057
Staple length	—.194**
Body weight	—.358**

** Highly significant at the 0.01 level of probability.

ing to have a slight, but highly significant, positive correlation with covering on the belly, and a significant negative relationship with fiber diameter, staple length, and body weight. It would appear that association of face covering with fiber diameter and staple length is an alternative expression of the much more direct influence on size. Since fertility data are not available at this age and the above correlation values do not reflect differences due to age, a more complete tabulation was made showing the relationship of age and face covering to body weight, fleece weight, and fertility. These data are shown in tables 2 and 3 for the first and second period, respectively. The results from the two periods are in very close agreement indicating that selection or management trends over the years have not greatly affected the results. Since the does were reclassified for face covering each spring the does did not necessarily remain in the same group in subsequent years. The total number of does involved in these studies was 790 or approximately 4486 doe years.

The amount of covering on the face did not significantly affect mohair production. The mean values for the various groups in both tabulations were essentially the same. Does with covered faces produced more mohair at the time of first shearing only, but this was insignificant as compared to the lifetime totals. Since the more open-faced does were heavier at most ages, the mohair production per unit of body weight was actually greater for the does with covered faces. It appears that the larger body size approximately counteracted the increased covering.

As indicated above, the amount of covering on the face had a significant and important influence on body size and fertility. Differences in fertility of the various groups were very marked, especially at young ages. As indicated in table 3, the 2-year-old does with covered faces produced only a 15.8% kid crop dropped as compared to 78.2% for open-faced does of the same age group. The lifetime averages reflect a 25% to 30% difference in fertility between the extremes in amount of covering. If more of the flock had been culled as the does passed the years of maximum production (approximately 7 years), the lifetime fertility record would have reflected still greater differences in favor of the open-faced animals. The proportion of open-faced does in the flock was somewhat less during the mature years. This probably represents the influence of visual appraisal resulting in heavier culling of the open-faced animals as they advanced in age. This resulted in a higher proportion of covered-faced does in the flock during the years of maximum kid production and thus tends to bias the lifetime average figures for kid production in favor of the covered-faced does.

Apparently much, if not all, of the influence of face covering is through reduced vigor associated with impaired vision. Due to the grazing habits of goats it appears that even a slight impairment of vision has a very marked influence. The immediate influence is on the size of the animal and this in turn seems to result in reduced breeding performance. Since

TABLE 2. THE RELATION OF FACE COVERING TO BODY WEIGHT, SPRING FLEECE WEIGHT AND KID PRODUCTION OF ANGORA DOES (1918–1933)

Type of face covering	Character measured	No. of animals	Doe age in years										Av.	Doe years
			1	2	3	4	5	6	7	8	9	10		
Open	Body weight, lb.	104[a]	49.0	60.8	65.8	71.5	74.1	78.0	78.8	81.5	79.3	78.7	71.8	577
	Fleece weight, lb.	107	1.8	3.8	4.0	3.4	3.5	3.4	3.3	2.9	2.5	2.6	3.1	601
	Kids dropped, %	107	....	70.1	85.1	88.3	98.3	94.2	100.0	92.9	100.0	92.3	91.2[b]	466
Medium	Body weight, lb.	213	47.4	58.4	65.4	69.1	74.0	73.9	76.8	79.5	76.2	73.5	69.4	1179
	Fleece weight, lb.	216	2.0	3.6	3.7	3.7	3.5	3.4	3.1	2.7	2.5	2.2	3.0	1214
	Kids dropped, %	216	....	54.2	74.0	76.0	84.3	90.4	94.7	89.8	94.1	96.7	83.8[b]	939
Covered	Body weight, lb.	180	44.0	54.7	63.6	69.8	70.7	76.4	75.0	76.8	74.9	73.3	67.9	823
	Fleece weight, lb.	186	1.9	3.3	3.6	3.7	3.6	3.5	3.2	3.0	2.7	2.2	3.1	860
	Kids dropped, %	186	....	27.4	54.5	71.7	82.1	73.9	80.9	70.4	75.0	55.2	65.7[b]	664

[a] The number of animals represents the number of does that were in the respective subgroups at two years of age.

[b] This average represents a grand mean of the respective subgroup means. Weighted means for percent kids dropped reflecting the number of animals in each age group are 86.7, 76.5 and 57.1 for the open- through closed-faced groups, respectively, and show slightly greater differences in fertility among the groups.

TABLE 3. THE RELATION OF FACE COVERING TO BODY WEIGHT, SPRING FLEECE WEIGHT AND KID PRODUCTION OF ANGORA DOES (1933–1946)

Type of face covering	Character measured	No. of animals	Doe age in years										Av.	Doe years
			1	2	3	4	5	6	7	8	9	10		
Open	Body weight, lb.	57[a]	45.5	56.1	63.6	68.7	71.2	75.0	74.1	72.5	73.1	75.2	67.5	356
	Fleece weight, lb.	57	2.7	3.3	3.8	3.8	3.4	3.0	3.1	3.0	2.6	2.3	3.1	360
	Kids dropped, %	55	....	78.2	83.6	78.3	89.5	97.0	89.3	85.2	100.0	78.6	86.6[b]	315
Light	Body weight, lb.	84	41.3	53.6	62.1	67.7	72.1	74.9	72.3	75.6	75.3	75.4	67.0	482
	Fleece weight, lb.	84	2.5	3.1	3.4	3.6	3.4	3.4	3.2	2.7	2.7	2.5	3.1	481
	Kids dropped, %	84	....	45.2	77.0	90.6	91.5	89.3	87.5	88.2	92.7	75.0	81.9[b]	360
Medium	Body weight, lb.	66	40.9	52.4	62.2	66.1	69.9	68.4	71.5	76.3	72.6	71.9	65.2	411
	Fleece weight, lb.	67	2.6	3.1	3.4	3.5	3.4	3.3	3.1	2.9	2.8	2.6	3.1	431
	Kids dropped, %	68	....	29.4	69.8	74.0	72.2	83.3	100.0	85.0	83.3	75.0	74.7[b]	342
Covered	Body weight, lb.	84	38.4	49.4	56.4	63.1	66.4	68.5	70.9	73.7	73.8	71.5	63.2	527
	Fleece weight, lb.	83	2.5	3.2	3.6	3.6	3.4	3.4	3.2	3.1	3.0	2.4	3.1	538
	Kids dropped, %	76	....	15.8	44.9	52.1	75.0	66.1	78.6	81.1	69.2	68.4	61.2[b]	479

[a] The number of animals represents the number of does that were in the respective subgroups at two years of age.

[b] This average represents a grand mean of the respective subgroup means. Weighted means for percent kids dropped reflecting the number of animals in each age group are 85.1, 76.7, 68.4 and 56.6 for the open- through closed-faced groups, respectively, and show slightly greater differences in fertility among the groups.

many of the covered-faced does are infertile during their early years in the flock they eventually regain much of the weight disadvantage in comparison with the more open-faced animals.

It seems likely that under conditions of heavy supplemental feeding, as practiced by many stud breeders, the influence of face covering would be partially masked. However, in commercial range flocks heavy supplemental feeding is seldom practical, and it is to these conditions that the breeding program should be directed.

Heritability Studies. The heritability of face covering was estimated by use of the methods of intra-sire regression of offspring on dam and paternal half-sib analysis, utilizing only scores assigned at one year of age. Both sexes of offspring were included. Based on 451 parent-offspring pairs the heritability estimate obtained by the method of intra-sire regression of offspring on dam was 53.0%. Paternal half-sib analysis, utilizing only data collected after 1933 (298 offspring of 23 sires) yielded an unrealistic estimate of 89.6%. Heritability estimates obtained by half-sib methods are frequently higher than those obtained by other methods due to dominance deviations or other forms of bias. In this case allocation of the does to the various males was not completely at random, and apparently this tended to bias the estimate upward. However, these data indicate that selection against face covering would be highly effective.

Summary

Data collected on a flock of registered Angoras maintained at the Sonora Station, (Texas Agricultural Experiment Station, Substation 14, Sonora) over the 28-year period (1918–1946) were analyzed to determine the influence of face covering on body weight, fleece weight and kid production. When expressed on a per head basis, face covering did not significantly affect grease fleece weight, but it had a very marked influence on body weight and kid production. Depending on the method of calculation, the open-faced does produced 25% to 30% more kids dropped throughout a lifetime in breeding flock than covered-faced does. The influence on fertility was much greater during the does' first years in the breeding flock. During the 1918–1933 period, open-faced does at two years of age produced 70.1% kids dropped as compared to only 27.4% for covered-faced does of the same age group. Similar data for the 1933–1946 period show an even greater contrast of 78.2 as compared to 15.8 for the open-faced and covered-faced does, respectively. It is suggested that the influence on fertility is brought about through reduced size and vigor resulting from the partial blinding effect of excess covering on the face.

Heritability studies, utilizing the method of intra-sire regression of offspring on dam, yielded an estimate of 53.0% based on 451 parent-offspring pairs. The method of paternal half-sib analysis yielded an estimate of 89.6%.

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DISTINGUISHED TEACHER AWARD

I. Name of Award: Distinguished Teacher Award of the American Society of Animal Production.

II. Donor: Swift & Co.

III. Nature of Award: $1,000.00 and plaque to one person each year.

IV. Purpose: Recognition of distinguished undergraduate teachers in Animal Husbandry.

V. Eligibility for Nomination:

Each nominee must:

1. Be a resident of the United States or Canada.
2. Be living at the time the list of nominees is presented to the Selection Committee.
3. Have demonstrated outstanding ability as an *undergraduate teacher* of Animal Husbandry.
4. Be a member in good standing of the American Society of Animal Production. Members of the Executive Committee are ineligible.
5. Be an active teacher at the time of the nomination and have been an active teacher for a period of not less than eight (8) years. This does not exclude section heads, department heads or deans, providing they were personally engaged in undergraduate classroom teaching during the school year immediately preceding their nomination.
6. Not have previously received this Teaching Award from the Society.
7. Be judged as a teacher on the following basis:
   a. His ability to motivate and stimulate students.
   b. The impression he has made upon his students by the mastery of his subject, his technique, vision and attitudes.
   c. Evidence of his interest in the improvement of teaching.
   d. The content and nature of the courses he has taught with emphasis placed on his responsibilities, organization of teaching materials, original contributions to teaching, and ability to translate research into terms of useful practice.
   e. Diversification of activities such as student counselor, coach of judging teams, training of students and placing them in positions for which, by natural endowments, they seem best suited, and activities in research. (Not all of these are essential as factors in consideration for the award.)
   f. Extracurricular activities beyond regular teaching duties.
   g. His service to agriculture and related industries.

VI. Nomination for the Award:

1. Any active member in good standing of the American Society of Animal Production may make a nomination, except if such a

member is a member of the Selection Committee for the Teaching Award.

2. A member may nominate no more than one person in any one year for the award.
3. Nominations (initially consisting of the name and address of the nominee along with a brief but pertinent justification) are to be sent to the Secretary of the Society.
4. Nominations must be in the hands of the Secretary of the Society not later than June 15 of the calendar year in which the award is to be made. Nominations received subsequent to this date will not be eligible for consideration.
5. Following receipt of the nominations, the committee chairman will designate a Principal Nominator for each nominee who will then proceed as indicated under Section VII, 7(c).

VII. Award Selection Committee:

1. The award selection committee shall consist of five (5) members. The committee chairman shall rotate among the vice presidents of the parent society (the sectional presidents); two members of the committee shall be carried over for a two-year period.
2. Eligibility for committee membership:
   a. Each member of the committee must be a member in good standing of the American Society of Animal Production and be actively engaged in or exhibit a strong interest in teaching.
   b. No member shall serve for two (2) consecutive terms.
3. Appointments to the Committee:
   a. The Executive Committee of the Society shall make all appointments of members to the committee in regular order, and the president shall make appointments to fill vacancies due to resignation or other causes.
4. Disqualification of Committee Member:
   a. In the event that a committee member is nominated for the award, he becomes disqualified for service on the committee for the period in which he is under nomination. The Society Secretary shall notify the President of this fact.
   b. The President shall request the member concerned to step down and make an interim appointment to the Committee for the period during which the disqualification is in effect.
5. Duties of the Members of the Committee:
   a. The sole purpose of the members of the Selection Committee is the selection of the Award recipient. The members shall be the sole and final judge in selecting the Award recipient from the list of names submitted by the Society Secretary.
   b. The ballots of the Committee and all results of balloting shall be held secret by the chairman except that the name of the

recipient shall be divulged to the Society President and Secretary and the Committee members only after the final ballot has been taken.

c. Communication about nominees between Committee members (other than the chairman) and nominators shall not be permitted during the balloting period. For this purpose, the balloting period is defined as the interim between reception of the nominee list by the Committee and the completion of final balloting.

d. Each member of the Committee shall receive from the Committee Chairman a complete dossier for each nominee and shall return this to the Committee Chairman at the conclusion of the selection of the recipient.

e. Any member of the Committee may ask the Committee Chairman to request additional information about a nominee from the Principal Nominator. Such information must be forwarded to the Committee Chairman, who will transmit it to all members of the Committee.

f. Balloting must be completed in time to have the final result in the hands of the Society Secretary not later than September 15th.

g. The Award may be omitted in any year that the members of the Selection Committee decide that no deserving candidate has been nominated.

6. Duties of the Committee Chairman:

a. Receive from the Society Secretary the list of nominees, a certification that nominees are members in good standing of the American Society of Animal Production, and biographical forms and copies of the specifications covering the award.

b. Check to be sure that each nominee is eligible as set forth under the regulations governing the award.

c. Select a Principal Nominator for each nominee. If the nominee has been nominated for the first time, ask the Principal Nominator to counsel with all other nominators (if any) to secure and prepare five (5) copies of each of the following items and forward them to the Chairman of the Committee not later than July 15th.

1c. Biographical sketch of the nominee.

2c. Letters in support of the nominee from not less than five nor more than ten current and/or former students.

3c. Letter from at least one (1) representative of the nominee's institution reporting on the nominee's activities in the areas defined in paragraph 7c, d, e, and f of Section V. of the rules of procedure.

4c. List of materials developed and/or published by nominee. This may include items useful in teaching Animal Husbandry such as course outlines, curricula, books, research reports, visual aids, charts, tools or other contributions.

5c. Letter from at least one, but not more than four (4) persons representing agriculture and related industries, showing the service of the nominee to Animal Agriculture.

d. If the nominee had been nominated in any prior year, send to the Principal Nominator the nominee's old dossier, ask him to bring it up to date by preparing five (5) copies each of the new material and to forward the revised dossier to the Committee Chairman not later than *July 15th*.

e. Check information and data received from the Principal Nominator and be certain that each nominee's file is complete and in order before calling a meeting of the Committee.

f. Conduct a poll by mail of the Selection Committee to determine the recipient.

g. Notify the Society President and Secretary that balloting has been completed and confidentially divulge to them the name of the elected recipient.

VIII. Duties of the Society Secretary:

1. Send notices of nominating deadlines to all active members in good standing of the American Society of Animal Production.
2. Receive all Award Nominations.
3. Check to determine the nominee's membership in the Society.
4. Check the list of nominees to see if any member of the Selection Committee has been nominated. If so, notify the President of the Society.
5. Send the list of nominees for the Award and copies of the Award procedure to the Chairman of the Selection Committee by June 15.
6. Maintain a file of past nominees for the Award.

IX. Balloting:

1. A majority vote of the five members is necessary.
2. Progressive balloting will take place, if necessary until three or more of the members of the Committee shall have named one (1) nominee as their first choice.
3. On the first ballot each Committee member will make known his first, second, third, fourth and fifth choices.
4. Each ballot shall be marked, signed by the member of the Committee, and returned to the Committee Chairman.
5. If none of the nominees receives a majority of first choice selections on the first ballot, balloting shall be repeated until election of the recipient occurs.
6. The Committee Chairman will weigh and tally the ballots as follows:

a. First ballot—first choice, 5 points; second choice, 4 points; third choice, 3 points; fourth choice, 2 points; fifth choice, 1 point.
b. Succeeding ballots—first choice, 3 points; second choice, 2 points; third choice, 1 point.

7. Nominees will be eliminated from consideration on succeeding ballots on the following basis:
   a. After totaling the weighed points for the various nominees on the first ballot, the Committee Chairman will eliminate from further consideration all but five (5) nominees highest in the standing.
   b. On succeeding ballots the Committee Chairman will eliminate from further consideration that nominee lowest in the point standing.
   c. The Committee Chairman shall exercise his best judgment in the process of elimination and shall be guided by the closeness of the point standing and the presence of ties in the point standing.
8. If on any ballot one nominee receives three or more first choice votes that nominee shall be declared the recipient of the Award and the balloting shall be closed.
9. At no time during the course of balloting shall the Committee Chairman divulge to the members of the Committee the point totals received by the nominees in the balloting.

PROCEEDINGS OF THE 51st ANNUAL NATIONAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meeting was held in the Hotel Sherman, Chicago, on November 27–28, 1959, the general session convening at 11 a.m. the first day and divided sessions for presentation and discussion of research papers in Breeding and Genetics, Extension, Meats, Nutrition, Pasture and Forage, and Physiology being held from 9:30 to 11 a.m. and from 1 to 4 p.m. the first day, and from 9 a.m. to 4 p.m. and from 7:30 p.m. to 10 p.m. the second day.

The annual dinner was held at 6 p.m. November 28, with J. K. Loosli, Vice-President, in charge. The guest speaker was Russell L. Moberly. The annual business meeting with W. P. Garrigus, President, presiding was held immediately after the dinner.

GENERAL SESSION

INTRODUCTORY REMARKS

W. P. GARRIGUS, *President*

Members of the Society and Honored Guests:

First, let me thank you for the privilege of serving as your President during the past year. It has been a rewarding experience. Also let me publicly thank the many members who have served your Society on its various committees. Special thanks are due your most able Secretary, Dr. H. H. Stonaker. Few can appreciate the heavy load that our Secretary carries for his three-year term.

This annual meeting marks the beginning of the second half century of service by this Society to the livestock industry. Your officers are pleased to report substantial progress for the year in terms of an ever expanding membership, a stronger Journal of Animal Science and especially in terms of two new national awards for Animal Husbandry Teaching and Animal Husbandry Extension. As you know, these awards are being sponsored by Swift and Company and Chas. Pfizer and Company on a more or less permanent basis. We feel that these awards will bring added incentive to these important segments of our total program. They will also bring due recognition to outstanding individuals for efforts that might otherwise receive only local notice due to their relatively unspectacular nature.

I am happy to report that our membership as of November 1 is 1,950 or 121 over that of a year ago. During 1959 the Journal of Animal Science contained 1596 pages, which represents an increase of 300 over any previous volume. Abstracts of papers presented at the three sectional meetings are being printed in the Journal. The Monograph on "Techniques and Procedures in Animal Production Research" is now ready for publication after 9 years of preparation. The possibility that this may be published free to members is under consideration. Registration at our annual meeting has continued to climb. In 1955 1,000 were registered. In 1956 registration increased to 1,050 and in 1957 it reached 1,160. Our attendance last year reached a record total. The figure for this year is, of course, incomplete at this time.

Your President feels rather deep concern over the growing tendency to oversimplify the role that animal science is playing or will play in American agriculture. It is my conviction that our profession will maintain or improve its present prestige only if we attract and train an increasing number of young men with outstanding potential. I am afraid that we have not done a thorough job of this in the past. For instance, a recent survey of 12,000 top high school students indicated that less than 1% would select agriculture as their profession. All of us have seen young men of exceptional promise select engineering, commerce, mathematics, medicine or other

fields even though they have a farm background and a real interest in livestock. While we should never hope to retain all of these individuals in animal production or even in agriculture as a whole, nevertheless we should be getting our fair proportion of them. Your Society is concerned with this project. Steps are being taken to achieve this goal and further consideration will be given to it in the future.

In the view of the urgency and seriousness of the matter and recognizing that the essential brevity of my remarks may lead to conclusions that I, too, am biased in my viewpoints, I now propose that we resolve our approach into its simple ABCs.

A Stands for Aggressiveness. The livestock profession has been characterized by its conservativeness and independence. All of us are proud of the fact that we have not run to Washington for aid whenever the price of livestock has declined. Nor have we tolerated interference by politicians or economists who would force us to abide by complex programs and artificial restrictions. Yet these admirable characteristics have frequently resulted in our being forced into a secondary or background situation by our more aggressive and politically minded colleagues in other disciplines. Many leaders seem to believe it to be more important to devise new marketing procedures for unsuitable products than to develop the means for producing more acceptable products at less cost. It is high time that the livestock profession realized its importance and insisted on its fair share of funds, personnel and programs at our land grant institutions and throughout the country.

B Stands for Balance. New brooms are supposed to sweep clean yet sometimes in the process they sweep away established programs and policies that should be retained. Our profession has been hurt from within its own ranks by criticism of such well established programs as livestock judging teams, meat judging teams, purebred herds or flocks and the various production courses. These criticisms have usually come from those not familiar with the programs and more concerned with the scientific aspects of our profession. It is time that all interests in our profession realize that we must work together to present a balanced program that will serve all phases of our industry. This program must appeal to our top high school graduates, whether they intend to train for farming, agribusiness, teaching, extension work, or research. A balanced program will do this, whereas one leaning too far in either the practical or the theoretical direction will fail to attract some of our best propects.

C Stands for Courage. Good teachers learn that it takes courage to teach a stiff course; yet students will always respect such courses and their teachers, and in the long run will patronize them in preference to easy courses. Sometimes it takes courage to defend the maintenance and improvement of purebred flocks and herds when some of our "top brass" is convinced that such are outdated and superficial. It usually takes courage to "sell" some purebred breeders on the merits of performance testing and

selective breeding or on the usefulness of artificial insemination in the further improvement of our breeds. It takes courage to turn down such commercial grants that carry with them conditions not up to the standards of an institution. It also takes courage to withhold preliminary research results that show real promise but need the support of one or two more years of intensive work before conclusions are drawn and recommendations are made. It takes courage to hold our ground on the content of curricula when our colleagues from the other side of the campus contend that production courses are strictly vocational and have no place in a college curriculum. The truth of the matter is that a majority of our college courses today contain much vocational training, whether these courses be in engineering, chemistry, commerce, art, geology or in many other departments.

In summary I would urge that all of our members take a broad, intelligent look at our profession and make plans to strengthen it in every possible way. The livestock industry is facing a period of tremendous change. It will require many men of intelligence, personality, great skill, and more complete training than we have given them in the past. If programs such as the training of judging teams will attract and inspire top young men toward graduate training for a career in teaching, research, or industry, let's recognize this fact rather than criticise such activities for their seemingly inadequate and superficial nature. Let's resolve our differences and employ our best talents so that our profession may successfully meet today's challenge.

THE FUTURE OF ANIMAL AGRICULTURE

H. M. Briggs

President, South Dakota State College, Brookings

Animal Agriculture really sounds like a simple process—but producing feed and using the animal to transform it to human food can "tax" the best in science. It is time we give serious thought to the future of this program that supplies a large portion of the food that crosses the American table.

Progress Came Fast

Animal Agriculture goes back as far as the recording of the Egyptians, or over 4000 years ago. In much of the history of agriculture there is very little change, but in recent years progress has been rapid. If we would let the distance between here and Ames, Iowa, which is approximately 400 miles, represent the recorded history of agriculture, we would find some interesting analogies. If we were to start from Ames and travel to this meeting as a journey through history, we would find very little happening for the first 260 miles of the trip. One hundred and forty miles out of Chicago we would see the first improvement in livestock, the development of the Arabian horse. We would be within twenty miles of Chicago before we would meet Robert Bakewell, the father of animal breeding. Another mile down the road we would run into the Collings brothers, and at about 11 miles out we would see the formation of most of the breeds of livestock.

At a section line 8 miles from here things would start to happen, because we would see Gregory Mendell, who gave us the basis for scientific breeding of plants and animals. At the sign post we would also see the Englishmen, Lawes and Gilbert, and the German chemist, Leibig, who contributed so much to the background of livestock feeding. Five and two-tenths miles out we would find Armsby at work at his early nutrition studies, and at five and one-tenth miles see him assume the first presidency of the American Society of Animal Production. Three and nine-tenths miles away we would see the draft horse reach his zenith, but from there on in, he rapidly would disappear and the tractor take his place. Three miles distant you would see the first developments in physiology research that affect our animal production, and from then on progress would be accelerated. Most of the developments in hormones and antibiotics would have occurred after we reached our hotel, and much of it between this platform and the elevator door.

Some may be of the opinion that since we have made such rapid progress in the past that most of the worthwhile things have been done. On the contrary, we have just begun to see the beginning of a scientific and more

rapidly changing agriculture, particularly as it is applied to meat-producing livestock. Technology is just entering this field of animal agriculture, and technology has its derivation from Greek and means "a bag of tools". Today we have tools never before available to research. If a person had used the term bionucleonics in this society a few years ago, there would have been few that would have grasped its meaning. Today the tracer technique is used in virtually every experiment station. Rapidity of progress should not be our chief concern; what should concern us is that we may not comprehend a trend until "the parade has passed".

Progress Not Uniform

Certain segments of animal agriculture have been making great strides, but progress has not been uniform. The production of a five-inch eye in a 220-pound hog is a noteworthy achievement. While only a few individuals make that today, progress has been so rapid in improving the meat production qualities of swine that in a few years this may be below the mean accomplishment. While improvement in breeding and nutrition has made considerable progress, there is still much to be done in translating the results of research to pork chops on the plate.

Unfortunately, the progress in beef and lamb breeding and nutrition has not been nearly so rapid. Unless both beef and lamb production are increased approximately 25 percent in the next quarter century, they may be in serious trouble. Rapid progress in ruminant nutrition is impending. Certainly, it has lagged far behind the progress that has been made in the animals and birds with a simple digestive tract.

Meat for the New Millions

We are on the edge of a great population expansion. It is estimated that today we have 178 million people in the United States, but population experts predict that by 1980 there will be 260 million if our 1955–57 birth rate prevails. There is no indication that it won't. If it does, it means that we will have some 82 million more people to feed in the United States than we have today. Think what that means in terms of agriculture if we continue to use the animal products at the rate we consumed them in 1958—81 lb. of beef, 8.8 lb. of veal, 66 lb. of pork, 4.1 lb. of lamb, or a total of 158 lb. of red meats. If we add to that another 35 lb. of poultry, we find that the total meat consumption last year was 193 lb. per capita. That may not sound like much, and it would be less than one-third the capacity of an 18-cubic-foot freezer.

However, when we relate today's consumption rates to the expanded population, the figures are really astronomic. In beef cattle, it will take over 483,000 cars of cattle to supply the increase in population. It will take 450,000 single decks of hogs, and another two and one-half million

head of lambs. We must not forget that animal agriculture includes both poultry and dairy, and the increased demand for milk will require approximately 266,000 tank trucks of 2500 gallons each. That is a lot of milk from a lot of cows. In the field of poultry, just in eggs alone, it will take 77 million 30-dozen cases by 1980 to feed the expansion. Anyone that doesn't think that animal agriculture has a future should ponder those figures.

The Future in Research

Let us reflect on the place of an animal husbandman in the animal agriculture of the future. The consumer is not going to be particularly concerned about who supplies the product, or how it is produced. In sharp contrast the future should concern every teacher in the classroom, every extension man in the field, and every research man in the laboratory or feed lot. Does your job and the way you are doing it have a place in the animal agriculture of the future?

The public relations of animal husbandmen to the farmers and ranchers of this nation have been excellent. Unless we continue to serve the public that has so generously supported us, our field may rapidly lose not only in prestige but financial support. Animal husbandry has had a great tradition of working closely with the producers on the land. Whenever that relationship declines, we will lose a large amout of support we have from the public.

Arguments concerning the relative advantages of basic or applied research are academic and are a waste of time. The history of research is replete with examples of studies that were originally of an applied nature but eventually opened doors to basic concepts the worker had the insight to appreciate and to properly identify. We are all keenly aware that it is the most basic studies that give us the tools used in solving problems in the applied category.

A high percentage of the research work in animal agriculture is of the applied type, but for this there need be no apology. It is this kind of work that has been used to justify tax-supported programs in all experiment stations. Practically all commercial grants for research are made for other than basic studies.

In recent years much "product testing" has been referred to as research. Much of it may lack imagination and foresight and is not worthy of the name. It is possible that a few dollars of grant money extracts more effort from a worker and his graduate students than an objective appraisal would justify. Having a graduate student follow a designed pattern of product testing is not necessarily creative, and may leave him far short of the desired goal of becoming a prospective staff member that can comprehend a problem and organize research that may lead to its solution.

There is no question there will be a future for the well-trained scientist.

There will always be a demand for the person that can handle production. The future for many in the "twilight" zone is not so encouraging. An analogous situation has developed in many professional fields, such as law and medicine—a top general practitioner is more sought and respected by the public than a second-rate specialist.

Others in Animal Agriculture

In recent times, we have found many disciplinary areas concerned with animal agriculture. Unquestionably most have a place, but the animal scientist must be in a position to lead, or at least work with the other disciplinarians. If he does not, they alone will capture the imagination of the public and animal science will be relegated to a declining portion of the research and operational budgets.

Most of you are aware of the great problems we have in marketing. In recognition of this, Congress and in some cases state legislatures have made considerable sums available for marketing research. At many experiment stations, earmarked monies have exceeded the 20 percent specified by Congress. There is nothing in the law that states that a "real sharp" animal scientist cannot engage in research that can very well be supported by marketing funds. In fact, there are a number in this room that are already using such funds to very good advantage. I am not suggesting that we all become economists, or that we imitate any other discipline because it may be more in the limelight at the present than it was in the past. However, the animal scientist cannot forget that much of his support has come from the ranchers and farmers. If we engage only in basic research and the farmer does not know what we are doing, then we cannot expect Mr. Taxpayer on the land to feel that we are solving the problems for which he feels he needs answers.

We must remember that animal agriculture is taking the products of the soil and processing them through the medium of the cow, the pig, the ewe, the hen, and the milk cow. The more people that translate the results from our laboratories and research the less our support will become. We must not forget that we in animal science are trying to improve animal agriculture.

Teaching, a Key

For many years members of our society have been concerned about teaching. If we are to continue as a worthwhile disciplinary area, we must have good teaching and must foster the training of the kind of specialists in our classrooms that can either go out and produce, or work with those that can produce.

Neglect in teaching becomes especially apparent in the first ten to fifteen years after students leave our classrooms. The future of animal science

and animal agriculture depends more upon teaching than any other thing. Here is the source of our practitioners, our research workers, extension personnel, and those upon whom commercial interests must depend.

Animal husbandry has been a prestige curricula at many institutions. The job done in the immediate future will determine if it will remain so. Minimizing the importance of good teaching is ludicrous.

Producers have been concerned about integration in the last few years; frankly, there is little to worry about. Size or complexity is no guarantee of efficiency. However, it is efficiency that will determine in the long run who does the producing. We have billions of tons of forage and grain that must be converted into human food. It is the producer that does the job most economically who will remain in business over a period of time.

We occasionally hear that large concerns engaged in the production or processing of animal products prefer to hire men trained in business, in engineering, or in some discipline other than animal science. If this is true and if it continues, we might well observe that our day may be "spent". I frankly don't believe it is true, but I think we must be cognizant of the changes that have taken place, are taking place, and will take place, or it will come true.

Can We Compete?

It really doesn't help to criticize the dean of the college or the director of an experiment station, because we are not getting the support we would like to have. Naturally, it is easier to complain that another department or disciplinary area is growing too fast and is taking away what "belongs" to animal husbandry than it is truly to evaluate a situation and develop solutions. Those that produce get! Any other concept is fallacious. There is value in "can do" in both curricula and research. Animal science professional staff, be they teachers, research workers, extension specialists, or a combination of the three, must be innovators and not just followers.

In recent weeks and months many farmers, ranchers, feed dealers, college presidents, deans, experiment station directors, and heads of animal husbandry departments have been asked a similar question, "What do you think are the big problems ahead for animal husbandry?" Invariably the answer has consisted of two parts—(1) The problem of adapting the teaching program to the agriculture of the future, especially animal agriculture, and (2) perform the kind of research that serves the man on the land.

When we ponder the question of who will control red meat production in the future, we face a number of challenges. We have a job to do in the business of producing meat for the American table and we cannot do it by just being worshippers at the "shrine of the past".

It will take our best efforts in the classroom, in the laboratory, and in

getting the best methods in practice on the farm and range. Less than this will lead to failure on our part to deliver what the public expects of us.

Several specific challenges that can be enumerated are:

1. Develop a teaching program geared to the next 25 years—our students of today should reach their zenith in the next two and one-half decades.
2. Conduct research geared to the problems of converting the produce of the land to animal products.
3. Adopt a realistic approach to helping producers supply what the market demands in animal products.
4. Remember that animal science should be interested in, and a part of, animal agriculture from the soil to the dinner plate.

The late Charlie Kettering enjoyed giving his version of the second law of thermodynamics—"You can't push on something that is already going faster than you are". Are we moving fast enough to have much influence on animal agriculture in the next quarter century?

The torch has always been the symbol of knowledge, but knowledge must be used. This is illustrated by the story of the colored man that lived in the swampy section of the South. He was approached by a visitor with the statement, "Sam, I understand that if one carries a torch alligators don't bite". Sam reflected a moment and replied, "Boss, that all depends upon how fast you is carrying the torch!" Our place in animal agriculture may to a large extent depend more upon what we do than what we know.

A SUMMARY OF THE MINUTES OF THE 51st BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

H. H. STONAKER, *Secretary*
Colorado State University

The 1959 Annual Business Meeting of the American Society of Animal Production was held in the George Bernard Shaw Room of the Hotel Sherman, Chicago, Illinois, November 28, 1959, at 9:15 p.m.

President W. P. Garrigus called the meeting to order and requested approval of the minutes of the 1958 Business Meeting as printed in the Journal of Animal Science, Vol. 18, No. 1, 481–493, inclusive. It was moved by E. W. Crampton that the report be accepted, H. M. Briggs seconded, carried.

The Secretary's report was read by H. H. Stonaker as follows:

"Continued growth in membership, subscriptions and in number of papers presented at the annual meetings has taken place in 1959. Membership in the Society increased to 1,950. There was a net increase of 121 in total membership. The membership is distributed as follows: United States and Canada, 1,848 and other countries, 102. The latter included 31 ICA sponsored memberships. Registration at the 1958 meetings was 1,194.

"Subscriptions to the Journal of Animal Science increased by 15 to a total of 1,449. Five hundred eighty go to the United States and Canada and 869 go to foreign countries.

"There were 244 papers accepted for presentation and 30 papers to be 'read by title' for the 1959 program. In addition there were nine invitational papers or addresses. The following half day sections were planned by program committees: Breeding and Genetics, —3; Extension, —2; Meats, —3; Nutrition, —10; Pastures and Forages, —2; Physiology, —5.

"The Secretary-Treasurer-Business Manager completes his term of office with this meeting and should like to take this opportunity to thank the officers and many members for their very great helpfulness and cooperation. Appreciation especially is expressed to Mrs. Betty Lou Stonaker for her assistance in this office."

W. J. Loeffel moved approval, L. E. Johnson, seconded, carried.

The Treasurer's report was read by H. H. Stonaker as follows:

"Expenditures in 1959 were $41,398.70 with an excess of expenditures over income of $1,191.47. Extra expense in 1959 was primarily associated with the celebration of the Fiftieth Anniversary of the Society. Direct additional costs attributed to the Anniversary were $3,419.58.

"As of October 31, 1959 the American Society of Animal Production had total assets of $45,289.90 with a decrease of $1,191.47.

"The balance in the Morrison Award Fund was $4,549.07, leaving $40,740.83 in the General Society Fund."

J. K. Loosli moved acceptance, S. L. Hansard seconded, carried.

Excerpts of the Auditor's report were read by Dr. W. P. Garrigus and

the suggestion was made that those of the membership who wished to read the report in detail were invited to do so. C. M. Kincaid moved acceptance of the Auditor's report, Ralph Bogart seconded, carried.

The Business Manager's report was read by H. H. Stonaker as follows:

"Three thousand five hundred Journals were printed quarterly with an additional 300 copies of the Fiftieth Anniversary issue making an average total cost of $2.01 per copy. Three thousand, three hundred ninety-nine are being mailed to members and subscribers.

"The records of the Business Manager list the following back numbers of the Journal and proceedings available for sale:

JOURNAL OF ANIMAL SCIENCE

Vol.	Year	Complete volumes	Numbers of copies in single issues			
			No. 1	No. 2	No. 3	No. 4
1	1942	0	0	0	0	2
2	1943	0	3	0	0	0
9	1950	0	0	0	27	31
10	1951	0	0	73	0	22
11	1952	0	0	0	50	107
12	1953	4	19	54	40	4
13	1954	235	235	256	269	349
14	1955	17	41	52	51	17
15	1956	0	0	44	77	402
16	1957	143	149	143	161	150
17	1958	88	227	88	113	137
18	1959	0	0	0	73	

PROCEEDINGS OF THE SOCIETY

Year	No. of copies	Year	No. of copies
1915–16	38	1931	50
1922	52	1932	11
1923	45	1933	30
1925–26	33	1934	17
1927	45	1935	20
1929	21	1940	35
1930	21		

"These back issues may be purchased from the Business Manager at the following rates: Volume 1–9 $1.25 per copy; Volumes 10 through 17 $2.00 per copy and $6.00 per volume. Proceedings $1.00 each. Please add 25 cents for all foreign deliveries."

Larry Kunkel moved acceptance, J. E. Comfort seconded, carried.

W. D. Gallup read the Editor's report as follows:

"The four numbers of the Journal issued this year as Volume 18 (1959) contained 175 complete papers and 364 abstracts. The total number of pages including Proceedings and usual items was 1596, some 300 more than in any previous volume.

"The policy of printing abstracts of papers presented at sectional meetings was put into effect this year (1959) with publication of the Southern and Western section

abstracts in the August issue. These abstracts are identified in the annual index by an asterisk.

"Rules for the new Extension Animal Husbandman's Award and for the selection of Fellows of the Society were published in the May issue. Short biographical sketches of the first members honored with the title of Fellow were published in the February issue.

"During the past 12-month period, November 15, 1958, to November 15, 1959, a total of 188 manuscripts were received for publication. Of these, 68 have been published, 41 are in press for the February (1960) issue, 23 have been withdrawn, or found unacceptable by the review board, 20 are being revised and 36 are in the hands of reviewers.

"The editor and the associate editor, A. B. Chapman, express their gratitude to O. G. Bentley and L. E. Hanson, whose terms expire this year, for their valued aid and contributions of specialized knowledge in the reviewing of papers during the past four years."

W. D. Gallup moved acceptance, J. K. Loosli seconded, carried.

The report of the Nominating Committee, consisting of J. C. Miller, Chairman; P. S. Shearer; and B. L. Southwell was read by Dr. W. P. Garrigus.

"On behalf of the nominating committee, I wish to make the following report. The nominating committee, after carefully screening the most likely prospects for Secretary-Treasurer, has voted unanimously to submit the following names: (1) Dr. J. C. Hillier, Professor of Animal Husbandry, Oklahoma State University and (2) Dr. Clair E. Terrill, Chief, Sheep, Goat and Fur Animal Research Branch, U. S. Department of Agriculture.

"These men have been contacted and each has given permission for his name to be submitted in nomination for the office of Secretary-Treasurer of the American Society of Animal Production at the 1959 meeting."

L. E. Johnson moved acceptance, L. H. Blakeslee seconded, election by acclamation of J. K. Loosli as President of the Society. Carried.

Ralph Bogart moved, A. B. Pearson seconded election, by acclamation, of H. H. Stonaker as Vice-President of the Society. Carried.

C. M. Kincaid moved approval, W. J. Loeffel seconded, of the report of the Nominating Committee. Carried. C. M. Kincaid, A. L. Musson, J. B. Outhouse were appointed by W. P. Garrigus as tellers.

Carl Neumann read the report of the Information Committee as follows:

"Reporting briefly on the press work of your committee for the Golden Jubilee Meeting, last year, 1958, as you may remember we maintained a press room during the three days of the meeting. This was visited in great numbers by editors and reporters of farm and breed papers across the nation. Many members called to pick up some of the releases of especial interest to them.

"We had in mimeograph form releases on all of the papers contained in the Golden Anniversary of the Journal of Animal Science, releases of the awards, and of the summary of principal speeches made at the meeting.

"Following the meeting, your committee saw to it that releases of special interest to certain areas were sent to all the media of farm communications within that area.

"We wish to express appreciation for the wide use made of this information by radio stations, farm press, breed, and special livestock magazines and market papers.

"While no clipping service brings in anything like complete reports of usage, we

know from actual counts of clippings received that well over 100 publications, including daily and weekly newspapers and publications of the livestock and meat industry carried information received from your committee.

"The list of all is too long for mention at this time, but some examples are: Electra (Tex.) Star-News, Clinton (Iowa) Herald, Topeka (Kans.) Capital, Hartford (Conn.) Courant, Temple (Tex.) Record, East Lansing (Mich.) State News, Indianapolis (Ind.) Star, Stearns (Ky.) Record, Chicago Drovers Journal, Omaha Daily Journal Stockman, Kansas City Drovers Telegram, The Cattleman, Hereford Journal, Record Stockman, Shorthorn World, National Wool Grower, American Cattle Producer, Aberdeen Angus Journal, National Hog Farmer, Montana Stockgrower, Nat'l Livestock Exchange Reporter, Indiana Farmer, St. Louis Live Stock Reporter, Gulf Coast Cattleman, Livestock Breeder Journal, Spotted Poland China Bulletin, Western Livestock Journal, Feed Age (New York, N. Y.), Oklahoma Live Stock News, Weekly Star Farmer, St. Joseph Stock Yards Journal, Kansas Stockman, Ohio State Grange Monthly, National Live Stock Producer, Breeder's Gazette, The Ranchman, Poland China World, Texas Hereford, Brangus.

"In addition there was much on-the-spot radio and television coverage, including an entire Arthur Godfrey show telecast from the Society's exhibit at the International, carried by 121 stations in 41 states.

"We invite you to visit the press room which we are again keeping open this year, so that reporters and editors may be served with information about the important work of the world being done by this Society and its members.

"We have prepared releases from several selected reports in the Journal of Animal Science, releases of the awards and of the main speeches. The interest in these is especially good and we urge upon all editors, and especially the science editors and radio farm reporters, to avail themselves of this prepared material. For their benefit, in most cases we have included reference by number to the specific reports excerpted. We wish that it might have been possible to include releases about more of the Journal reports, but enough have been included to give science editors direction as to where to look for this valuable material.

"All Chicago news outlets have been contacted this week with information releases, and your committee will do a thorough follow-up to ouside media in the days ahead. Advance announcement of the meeting went out to 85 market papers, 189 Radio Farm Directors, and to the farm press, extension editors and others.

"In this release the extent of the work done by men in animal science was stressed. The reports to this meeting of animal science researchers cover work with 47,362 cattle, 10,336 hogs, and 9,183 sheep.

"These animals were used in a variety of carefully controlled and evaluated experiments ranging in time from a few weeks to eight years.

"Experiments covered dozens of different subjects. A variety of research methods were utilized . . . from scientific laboratory examinations of bacteria, to studies involving as many as 23,000 head of cattle on 42 ranches in 12 states.

"Most reports are by workers in Land Grant Experiment Stations. However, reports of five commercial companies—Armour, Swift, American Cyanamid, Ralston Purina, and Pfizer—add to the volume and significance of the technical experimentation and findings being covered at the meeting.

"Study of the geographical distribution of these reports shows that, of 9 mid-west states, Iowa leads with 14 reports. There are a total of 74 reports from the midwest.

"Emphasis on animal research in Florida is indicated by the fact it is in a tie with Iowa for the lead in number of reports.

"Six southeastern states show 28 reports; four southwestern states, with Texas leading with ten, have 21 reports; nine western states with 34 reports show Nebraska and Washington tied with five each; and in four eastern states, New York (Cornell) leads with 9 of 13 reports.

"While these figures are not meant to be an exact indication of the total amount or significance of the animal science research in any area or state, they are of more than passing interest regarding the wide distribution of animal research in this country.

"Of the 276 experiments reported in the Journal of Animal Science, published by the American Society of Animal Production, 170 have indicated the number of head of livestock involved.

"The other 106 are reports of careful analytical work relative to digestibility of feed nutrients, factors which influence gestation in the female and potency in the male, effects of hormones, tranquilizers, trace minerals, enzymes, stilbestrol, Aureomycin, Terramycin, and most of the modern ingredients of rations used in the science of animal feeding and breeding."

Carl Neumann moved acceptance of the report, L. H. Blakeslee seconded, carried.

S. L. Hansard read the following report of the Research Committee:

"With completion of the monograph, activities of the Research Committee during the past year have been limited to efforts of establishing liaison with research committee of our various livestock organizations.

"The acknowledged success of the 1956 panel discussion on 'The Meat Type Steer', and the recognized need for renewed emphasis upon many phases of research in livestock production prompts this Committee to suggest that the Executive Committee of the Society give consideration to the *regular* inclusion of a greater number of symposia in the Annual Programs of the Society. It is believed that a balance of symposia type presentations and individual papers would result in a greater exchange of ideas and a greater stimulation for research in specific areas of need."

S. L. Hansard moved acceptance of the report, L. E. Johnson seconded, carried.

Clair E. Terrill read the following report of the Monograph Committee: Revision of the Monograph has been completed and the manuscript has been submitted to the Secretary of the Society for publication. It is recommended that the Committee be terminated with the publication of the Monograph.

The Report of the Teaching Committee is as follows:

"I. Committee Membership: Tom W. Glaze, R. H. Johnson, J. H. Kiser, J. L. Krider, G. L. Robertson, Roy M. Kottman.

"II. Report of Activities:

"The appointment of the Teaching Committee by Dr. W. P. Garrigus, President of the American Society of Animal Production, carried with it these items of information (quoted from the letter of appointment)—'Last year's committee, under the chairmanship of Dr. W. A. Cowan, is presently completing the Rules and Regulations for a Distinguished Teacher Award of the American Society of Animal Production. They have made some preliminary moves toward obtaining a $1,000.00 grant annually in support of this award. As soon as they turn over their finished rules, copies will be sent to your committee. You will also be kept informed as to any contacts that have been made with prospective donors.

" 'We hope to make the first award at our 1959 meeting. You will note that your committee contains two representatives of industry. Your Executive Committee felt that these representatives could aid the committee in formulating programs and

recommendations that would effectively serve the changing needs of our Animal Husbandry graduates.'

"The Rules and Regulations for a Distinguished Teacher Award which had been prepared by the 1958 Committee were circulated to members of the current year's committee for their suggestions. The committee was also solicited for suggestions concerning possible donors of the $1,000.00 needed if a Distinguished Teacher Award were to be made. The 1958 Committee had drawn up a list of thirteen potential donors. This list was expanded to twenty-four by the current committee.

"The Committee met at Chicago in the offices of the American Meat Institute on March 18, 1959, with Glaze, Krider, Kiser, and Kottman present. The Rules and Regulations governing the Distinguished Teacher Award were thoroughly discussed and a revised set of rules was drawn up. The revised rules were subsequently sent to Johnson and Robertson for their suggestions, and the approved Rules and Regulations were transmitted to Dr. Garrigus under date of March 26, 1959.

"The March 18 meeting was especially significant in that Mr. Tom Glaze of Swift & Co. indicated a strong possibility of his organization providing funds for the Distinguished Teacher Award.

"Notification of the fact that Swift & Co. had decided to provide funds for the Distinguished Teacher Award came to the Committee on April 24, 1959. The press release concerning this announcement is attached hereto. It will be noted that the Award is to consist of $1,000.00 and a commemorative plaque, both to be donated by Swift & Co., who have indicated that they expect to continue the Award indefinitely. A copy of the Rules and Regulations for the Distinguished Teacher Award of the American Society of Animal Production is also appended hereto.

"Still a further attachment is a memo addressed to the Executive Committee of the American Society of Animal Production, dated May 5, 1959. It is incorporated with this Committee Report because it provides additional background concerning the Rules of the Distinguished Teacher Award. Likewise, there is enclosed a copy of a letter from President Garrigus to Mr. Tom Glaze, dated April 28, 1959.

"The members of the Teaching Committee present at the March 18 meeting discussed various possibilities for a Teaching Program at the November 1959 Society meetings, and concluded that it would be appropriate to hold all of the Teaching portion of the program at the banquet on Friday evening, November 27. The Committee was unanimous in its recommendation that someone from business and industry be secured as the banquet speaker and be asked to speak on the subject 'Management Appraisal—Teacher Appraisal'.

"The Teaching Committee was advised by President Garrigus that the banquet program on Friday evening, November 27, 1959, was the responsibility of Dr. Loosli, Vice President of the Society. Accordingly, the matter of featuring a speaker selected by the Teaching Committee was taken up with Dr. Loosli and, in view of the fact that the first Distinguished Teacher Award was to be made at this banquet. Dr. Loosli agreed that it would be quite fitting for the principal speaker at the banquet to be selected by the Teaching Committee. Accordingly, the Committee agreed that invitational papers for a Teaching Section program would *not* be solicited as they had been in former years. Teaching Section programs in recent years have not been well attended since they have been held in competition with Research papers which teachers wanted to hear. Permission to proceed along these lines was received from Dr. Loosli under date of June 22, 1959.

"Under date of June 30, 1959, the names of eight potential banquet speakers were sent to the members of the Teaching Committee, and Tom Glaze was asked to assume the chairmanship of a Subcommittee consisting of himself and Dr. J. L. Krider in the selection and the sending of an invitation to a banquet speaker. The speaker selected by Mr. Glaze and Dr. Krider was Russell L. Moberly, Management Consultant, Milton, Wisconsin. Biographical data on Dr. Moberly follow:

"Russell L. Moberly is a graduate of the University of Wisconsin, holding three

degrees—B.M., M.A. and Ph.D. His major concentrations of study were Educational Administration, Finance, Business Management and Psychology. He has worked in Business and Industry as a production worker, office worker, supervisor, and top executive. He has taught in Elementary and Secondary schools, college and university.

"Dr. Moberly is former Director of the Management Center, and Professor of Business Administration at Marquette University, Milwaukee, Wisconsin.

"He has been active as a consultant to the Office, Chief of Ordnance at the Pentagon in Washington, and was instrumental in the establishment of a Management Training Center, located at Rock Island, Illinois, for all Ordnance installations throughout the country.

"He is in demand as a speaker on management problems and is called upon frequently as a consultant to Business and Industry. He is particularly noted as co-developer of the Mobell or Basic Abilities System of Salary and Wage Administration.

"He has been a National Regional Vice President and member of the Board of Directors of the Milwaukee Chapter of the Society for Advancement of Management, is past President and now Secretary-Treasurer of the American Society of Personnel Administration, formerly Secretary-Treasurer of the American Society of Training Directors, and many others.

"Dr. Moberly is an arbitrator on the National Labor Panel of the American Arbitration Association and is a member of the Conciliation Panel of the Wisconsin Labor Relations Board. He has published many books, pamphlets and magazine articles.

"He owns a stock ranch northwest of Milwaukee.

"The Committee appointed by President Garrigus to select the first recipient of the Distinguished Teacher Award consisted of Dr. A. E. Flowers of Montana, Dr. George Johnson of Ohio, Dr. R. M. Kottman of West Virginia, Dr. Bruce Taylor of Arizona, and Dr. C. S. Hobbs of Tennessee, Chairman. The first recipient of the $1,000.00 Distinguished Teacher Award and Commemorative Plaque was Professor John H. Knox, New Mexico State University."

R. M. Kottman moved acceptance of the Teaching Committee's activity in developing the rules for the Distinguished Teacher Award, A. M. Mullins seconded, carried.

M. D. Lacy moved acceptance of the activities of the Extension Committee in the preparation of the annual Extension Husbandman award. Special acknowledgement was given to Richard McWilliams, formerly of Iowa State University, who was chairman of the Extension Committee when this award was proposed and who was the first chairman of the Award Committee.

M. D. Lacy moved acceptance, Dean Stangel seconded, carried.

The Membership Committee's report was given by J. K. Loosli:

"The Membership Committee has nothing to report except—Members, 1,950—121 increase in 1959, which was already reported."

Seconded by Roy Kottman, carried.

The Committee of Tellers reported the election of Clair E. Terrill as the new Secretary-Treasurer of the Society.

J. L. Lush read the report of the Necrology Committee and moved its approval for publication in the Journal of Animal Science. L. E. Harris seconded, carried. A moment of silent tribute was observed in honor of the deceased members.

Dr. Garrigus referred to letters he had received for polling the membership again on time and place of meetings. He reported the action of the Executive Committee in determining to conduct a poll in 1961 upon only two alternatives insofar as the meetings are concerned, these being the No. 1 proposal vs. the No. 5 proposal.

Dr. Garrigus also reported that he and J. K. Loosli met with Dean Kildee, President of the Board of the International Livestock Exposition, discussing the scheduling of steer judging on Saturday which conflicts with the scheduled papers being read in the Society meetings. There was no comment from the floor.

Reports of Special Committees

T. C. Byerly, American Association for the Advancement of Science representative, read the following report:

"I participated in meetings of the A.A.A.S. Council on December 27–30, 1958. Among the resolutions adopted was one welcoming the National Defense Act of 1958 and confirming the principle that the Federal Government should share in the responsibility for the support of education.

"An excellent symposium on Water in Agriculture was held under the auspices of Section O, Agriculture. The symposium was of unusual excellence and the volume to be published will be of use and interest to many members of A.S.A.P.

"I was an invited participant at the Symposium on Basic Research held in New York in May, 1959 under joint sponsorship of A.A.A.S., Sloan-Kettering and NAS-NRC. The symposium proceedings have been published and contain several excellent papers including a statement of unusual interest by Dr. Tove of the Carnegie Institution.

"The 1959 Annual Meeting will be held in Chicago December 26–30. It will include an important symposium on germ plasm under auspices of Section O, and cosponsorship of A.S.A.P. Dr. Ralph Hodgson is symposium chairman and several members of this Society will participate."

T. C. Byerly moved acceptance, R. E. Comstock seconded, motion carried.

J. E. Foster read the report of the Scientific Manpower Commission which was as follows:

"The fifth annual report was presented at the business meeting of the American Society of Animal Production last year. Since then S.M.C. meetings have been held in Washington, D. C. on February 5, May 6, June 11 and November 4. The one in June was a meeting of the Executive Board. The Committee on Intersociety Cooperation met on January 21 to review the manpower supply problems in Animal Science and the salaries of Biologists and Scientists in the Federal Government. At the annual fall meeting of S.M.C. on November 4, your representative was renominated a Commissioner for another three-year term. Your society made a contribution again this year of $150.00 to the Scientific Manpower Commission.

"At your February meeting it was noted that gross expenditures for the calendar year 1958 had been kept below gross receipts for the year, but only because of rigid economies in operation, contributions of $4,625 from the Commission's nominating agencies, and a grant of $2,000 from the Alfred P. Sloan Foundation to defray the expense of publishing the Proceedings of the Chicago Conference. In view of this and the present financial status, as reported on November 4, the Commissioners were requested to again ask their respective societies for contributions to S.M.C.

"Throughout the year the S.M.C. staff and commissioners have devoted considerable time to the main objects of the commission which are 'the collection, analysis and publication of data regarding the manpower resources of the United States in the fields of science and technology; the promotion of programs of education and training of potential scientists and technologists; the promotion of the proper utilization of scientific and technological manpower by educational institutions, industry and government; all devoted toward aiding the development of our country's scientific resources for the benefit and welfare of our people'. In keeping with these purposes the following are some of the items that have been accomplished.

"1. A 1959 brochure to publicize the Commission's manpower activities has been prepared.

"2. Assistance has been rendered in connection with a national manpower policy, specifically in relation to the Draft Act, and in its endorsement for adoption by the Administration and by the Congress. It was the consensus that broader amendments should be introduced to enable proper and appropriate allocation of critical personnel to essential civilian activities.

"3. Assisted with plans and appointments to extend the activities of the Department of State in the fields of science and engineering. This may well lead to a Department of Science and Engineering.

"4. Worked on a joint committee with Engineering Manpower Commission on improving Department of Defense Contract Procedures.

"5. Commissioners served on a special subcommittee appointed to consider the program that the committee on Specialized Personnel, OCDM, will follow during the remainder of the year and in 1960.

"6. Participated in the Civil Service Commission's Conference on Scientific Manpower and in the Conference on Teacher Education.

"7. Passed resolution urging the retention of the Critical Skills Program, which the Department of Defense had announced its intention to terminate. This resolution will be brought before the proper military manpower officials.

"8. Prepared and published other brochures, the joint E.M.C.-S.M.C., Newsletter, numerous booklets, reports and letters, including frequent selective service letters.

"There will be a jointly sponsored Scientific Manpower Conference held in Chicago on December 28, 1959 at which S.M.C. will be represented by its Executive Director, Dr. Howard A. Meyerhoff."

J. E. Foster moved acceptance, A. M. Mullins seconded, carried.

Carl F. Sierk read his report on the National Research Council. The report was as follows:

"1. *Annual Meeting, NRC*

"The second meeting of the NRC as a body took place at the Academy-Research Council, March 19–21, 1959. Plenary sessions were held on Thursday afternoon and evening, March 19; and on Saturday morning, March 21. The plenary sessions included review of the activities of the Research Council since the last meeting, addresses on four main topics of interest to all Council members, and discussions of these addresses. The topics included:

"(1) The Nature and Conduct of Fellowship Programs in Science,

"(2) U. S. Science in Foreign Aid,

"(3) The Place of Behavioral Science in the National Research Council, and

"(4) Means and Patterns for the Support of Scientific Research.

"At the final plenary session, discussion groups presented reports on their deliberations together with their recommendations for further action on the part of the Research Council.

"2. *Annual Meeting, Division of Biology and Agriculture*

"All 34 of the member scientific societies were represented at the Division meeting

on Friday afternoon and evening of March 20. In addition to the Society representatives, the membership of the Division consists of ten members-at-large appointed by the President of the National Academy of Sciences, and 13 liaison members selected by the Executive Committee of the Division. The principal function of the members of the Division is to examine its work and try to guide it along lines of greatest need, interest, or importance to various branches of biology and agriculture, as well as to science, government, the national welfare, and human welfare in general. The meeting this year had two principal purposes: (1) to give the members information that they had not already received about the Division and (2) to provide opportunity for the members to be heard on any subject pertinent to the work of the Division.

"The Chairman of the Division gave an excellent review of the history, relationships, functions, and accomplishments of NAS-NRC and the Division of Biology and Agriculture. The Executive Committee is convinced that the Division must take the lead or participate in broad studies dealing not only with biology or agricultural natural sciences, or not only with natural sciences extending beyond the border of biology and agriculture into the subjects of other Divisions, but with natural and social sciences connected with agriculture and human welfare. The Executive Committee also favors the restoration of inquiries into factors affecting the development of biology in the United States, particularly educational policies, with special attention to factors conducive to the production of scholars in biology.

"Following the Chairman's presentation there were reports by leaders of the current activities of the Division, including (1) the Agricultural Board, (2) Agricultural Research Institute, (3) Food and Nutrition Board, (4) Food Protection Committee, and (5) Institute of Laboratory Animal Resources. A general discussion period followed these presentations which was analytical in nature and brought out a number of important points concerning the past and future activities of the Division.

"Since the annual meeting in March, four more societies have been accepted by the NAS-NRC governing board, increasing the number in the Division to 38. The new societies accepted are: American Society of Agricultural Engineers, Biophysical Society, Radiation Research Society, and Society of Protozoologists.

"A recent survey revealed that no less than 70 members of the Society of Animal Production are active on NRC committees. Some members serve on more than one committee. One of these committees evaluates applications for the National Science Foundation's Postdoctoral Fellowship Program. Thirty-five fellowship awards for advanced study and research were announced by NSF in October. Applications are now being accepted and evaluated for awards to be made in March 1960.

"3. *Annual Meeting, Agriculture Research Institute*

"The eighth annual meeting of ARI was held October 12–13, 1959, at the Academy-Research Council headquarters. The ARI supports the Agricultural Board, NAS-NRC, by: (1) serving as a forum for the discussion of problems of interest to agriculture in its broadest aspects; (2) developing proposals for the program of the Agricultural Board, which, when approved, might be accomplished by existing committees of the NRC or new committees; and (3) contributing to the financial support of the Agricultural Board and NRC committees. A total of 115 persons attending the meeting, including 38 Class A members representing agricultural industries, and 77 Class B members including State Agricultural Experiment Stations, Federal research agencies, and professional societies and associations. The following were activities of the Institute this past year of major interest to Society members:

"(1) Through the efforts of ARI the Agricultural Board has received from the Rockefeller Foundation a 3-year grant totalling $50,000 for studies of factors affecting national policy and planning agricultural research.

"(2) A national conference on the theme, 'Beef for Tomoorow', was held at Purdue University under the joint sponsorship of ARI, the Agricultural Board, and the Indiana Agricultural Extension Service.

"(3) The Committee on Agricultural Meterology and Climatology is preparing a

text to promote application of basic principles underlying plant and animal response. A symposium is also being planned.

"(4) The Committee on Agricultural Pests has been active in stimulating interest among research workers in accumulating and publishing data on losses from various pests, and relationships between biological control, and economics of crops and livestock production.

"(5) U. S.-Canadian tables on feed consumption prepared by the Subcommittee on Feed Composition of the Animal Nutrition Committee has recently been published by NAS-NRC as publication 659.

"(6) A Comprehensive revision of NAS-NRC publication, 'Nutrient Requirements of Swine', has been sent to the printers.

"(7) A revision of the NAS-NRC publication, 'The Fluorine Problem in Livestock Production', is in manuscript stage.

"(8) A revision of the NAS-NRC publication, 'Hormonal Relationships and Applications on the Production of Meat, Milk, and Eggs', have been brought up to date with a supplement (NAS-NRC 714) covering recent progress in this area of research.

"(9) The Committee on Fats and Oils expects to publish within the next six months a text on fats and oils to include sections on chemistry of fats, marketing demands, foreign trade and policy, production problems, and changing patterns of consumption.

"(10) A comprehensive text on 'Methods and Techniques in Range Management Research', prepared by the Committee on Range and Pasture Problems, is in the hands of the printers.

"A book titled, 'Symposium on Basic Research', has been published by the A.A.A.S., which together with NAS-NRC and the Alfred P. Sloan Foundation sponsored a symposium on basic research that was held in the Caspary Auditorium of the Rockefeller Institute, May 14–16, 1959. It was a gathering of people distinguished in science, industry, and government. The book contains invitational addresses by 16 of these leaders."

Carl F. Sierk moved acceptance of the report, J. K. Loosli seconded, carried.

In the absence of N. K. Joshi, E. W. Crampton approved publication, without reading, the report of the European Association of Animal Production. J. L. Lush seconded, carried. The report is as follows:

"During the year 1958–59 three special meetings were held. The first dealt with problems in energy metabolism, the second with the situation of the sheep industry in European and Mediterranean countries, and the third was a colloquium with demonstration in breeding and artificial insemination of pigs held at Jouy-en-Josas in France.

"The Study Commissions Meetings were held in Belgrade, Yugoslavia, during September 1959.

"Of the six Study Commission Meetings on Animal Nutrition, Cattle Production, Sheep Production, Pig Production, Horse Production, and Genetics and Breeding, the last named Commission could not hold its meeting this year.

"There were over 100 participants from 16 different countries.

"As in the past, the meetings of the Study Commissions were held concurrently.

"*Commission on Animal Nutrition*

"Discussions took place on the symposium on energy metabolism to be held at Wageningen in 1960. The main topic to be discussed at this symposium will be 'The net energy concept of measuring the food value of feedingstuffs'.

"Considerable discussion ensued relating to the guide for the digestibility of feeds,

standardization of the methods of feed analyses, and the establishment of tables on the composition of animal feeds.

"Commission on Cattle Production

"The Commission contained its study on the methods for organizing progeny tests for beef cattle. Four reports discussing 'Methods of Progeny Testing for Beef Production and Slaughter Quality in Cattle', 'Progeny Test for Beef Production in Cattle', 'Proposals for Organizing Fattening Tests to Evaluate the Qualifications of Progeny Groups in Cattle', 'Report on French Research Regarding Progeny Testing for Meat Production Characters in Cattle' were presented at the meeting.

"The Sub-Commission on 'Beef' is continuing its study on 'the possibilities for setting up a standard method of cutting up the carcass and to study the ratio between the evaluation on the hoof and of the carcass quality'.

"The questionnaire on the use of milk records in the selection of male and female breeding stock was discussed and approved. It is intended that such a study will be confined to the member countries of EAAP for the present.

"Commission on Pig Production

"A report on a colloquium on Breeding and Artificial Insemination of Pigs held at Jouy-en-Josas, France, in March 1959, was presented and discussed at the Commission's meeting. From these discussions it was evident that two difficulties limit the rapid extension of artificial insemination in pigs. The first is the number of spermatozoa to be used for each insemination—at present not more than 500 inseminations per boar per year are possible. The second is the difficulty in detecting oestrus in sows.

"Reports on the reliability of various estimates of carcass quality from measurements made on the live pigs for the purpose of performance testing of boars were also discussed.

"A joint meeting of the Animal Nutrition and Pig Production Commissions discussed a draft questionnaire on feeding standards for pigs.

"Replies from Governments received by FAO concerning the recommendations made at the meeting held in Copenhagen on Pig Progeny Testing were discussed. In view of these replies, it was suggested that 'international comparability' rather than standardization of methods should be adopted as a goal. In order that the progress in the development of methods for pig progeny testing be kept under review, a sub-commission was appointed. This sub-commission will report the progress from year to year.

"Commission on Sheep and Goat Production

"A final report on the symposium organized by the Italian Government in collaboration with EAAP and FAO during November 1958 on the Situation and Trends in the Sheep Industry in Europe with special emphasis on the Mediterranean region was presented at the meeting of the Commission and discussed. As a result of the recommendation of this symposium, a meeting for the study of the production and utilization of sheep and goats' milk in the Mediterranean region will be organized at Athens during the winter of 1960. FAO will collaborate at this meeting. A draft programme for the meeting was discussed and adopted.

"A report on the situation of goat-keeping in Europe was presented for discussion by Mr. H. Borger of Germany.

"Commission on Horse Production

"Verbal statements on the state of horse breeding were given by the delegates from different countries. Importance of meat production in horse breeding was discussed.

"After the Study Commissions meetings, an excursion was arranged by the Yugoslav Government. A number of livestock stations, artificial insemination centres and stud farms were seen during the tour."

L. E. Hanson moved publication of the Ralston Purina Award Committee report without reading, seconded by J. K. Loosli, carried.

"The Ralston-Purina Research Fellowship Awards Committee met in St. Louis,

March 30, 1959. The Committee was composed of five persons: R. H. Thayer, Oklahoma State University, representing the Poultry Science Association; J. B. Frye, Louisiana State University, representing the Dairy Science Association; Robert MacVicar, Oklahoma State University, representing the American Association of Land Grant Colleges and State Universities; C. A. Brandly, University of Illinois, representing the American Veterinary Medical Association; and L. E. Hanson, University of Minnesota, representing the American Society of Animal Production.

"A total of thirty-seven applications were reviewed by the Committee. This was a marked reduction in number of applicants from the previous year (60 applications in 1958). However, there was no reduction in quality. The average apparent quality of the applicants was of a very high order with many near perfect scholastic records. Awards were made on the basis of scholarship, undergraduate program, proposed research, recommendations and other pertinent data. One award was made in Veterinary Medicine and three awards in each of the following fields: Animal Husbandry, Dairy Husbandry and Poultry Husbandry.

"The awardees and the Graduate School in which each is taking or proposed to take his or her graduate training are as follows:

"Animal Husbandry: Earl F. Ellington (Univ. of California); Don O. Pinney (Oklahoma State University); and Margery J. Twombly (University of California).

"Dairy Husbandry: Emmett K. Inskeep (University of Wisconsin); Curtis W. Richardson (University of Missouri); and Alan S. Todd (University of Georgia).

"Poultry Husbandry: Bruce E. McDonald (University of Alberta, Canada); Thomas F. Simco (University of Arkansas); and Woodie P. Williams, Jr. (Texas A & M College).

"Veterinary Medicine: Max J. Freeman (University of Wisconsin).

"The Ralston-Purina Company is to be commended for making these awards available."

President Garrigus announced the establishment of a Committee on Special Grants for Foreign Study consisting of J. O. Grandstaff, Chairman, Gus Bohstedt, and K. L. Turk to handle opportunities for special travel grants.

The report of the Resolutions Committee was given by L. E. Casida and is as follows:

"The Resolutions Committee offers the following resolutions:

"1. Be it resolved that a letter be sent to the Hotel Sherman expressing our thanks for the facilities furnished us and for the assistance and courtesies shown us by the Hotel management.

"2. Be it resolved that our appreciation be expressed by the Secretary of the Society to the appropriate source for support of our awards program: for the continuance of the Morrison Award and the American Feed Manufacturers Association Award, and for the establishment of the Extension Animal Husbandry Award and the Distinguished Teaching Award.

"3. Be it resolved that in the adoption of this resolution, we express to the officers and Committees of this Society our thanks for meritorious service in our behalf during this past year. Particularly, we wish to single out the conscientious and painstaking efforts of Dr. H. H. Stonaker during his three years as Secretary-Treasurer for which we express our deepest appreciation."

L. E. Casida moved acceptance of the report of the Resolutions Committee, A. L. Harvey seconded, carried.

Meeting adjourned at 10:15 p.m.

THE MORRISON AWARD

1959

Lester Earl Casida was born at Chula, Missouri, April 9, 1904. He received the B.S. degree from Northeast Missouri State Teachers College and the M.A. and Ph.D. degrees from the University of Missouri.

Since 1929 he has held the following positions: Acting Head, Department of Biological Science, Arizona State Teachers College, 1929–30; Acting Head, Department of Agriculture, Arkansas State Teachers College, 1930–31; Fellow in Animal Husbandry, University of Missouri, 1931–32; National Research Council Fellow in the Biological Sciences, University of Wisconsin, 1932–34; Assistant Professor of Genetics, University of Wisconsin, 1934–39; Associate Professor of Genetics, University of Wisconsin, 1939–46; Professor of Genetics, University of Wisconsin, 1946 to date.

Dr. Casida's area of research has been the physiology of reproduction. In the past 32 years he has been the author or co-author of 132 scientific publications which have contributed greatly to our knowledge of the reproductive processes in dairy cattle, swine, sheep, poultry and laboratory animals. Areas in physiology of reproduction in which he has made significant contributions include:

1. The estrus cycle of the ewe.
2. Ovarian stimulation and ovulation through the use of gonadotrophic hormones.
3. Factors associated with breeding efficiency of dairy cattle.
4. Effect of dilution rate and number of sperm on motility and fertility of semen.
5. The nature of reproductive failures in dairy cattle, swine and sheep.
6. Alteration of the estrual cycle in the ewe, cow and sow with progesterone.
7. Puberty and related phenomena in swine and cattle.
8. The effect of various management practices and levels of nutrition on reproductive phenomena in swine and sheep.
9. Factors affecting the response of the uterus to induced infection.

As can be seen from the above Dr. Casida has always emphasized basic, fundamental research. Much of his work has been aimed at determining the normal pattern and the amount and causes of variation in various reproductive phenomena. In his studies of reproductive failures he has sought first to determine the nature and causes thereof before making any attempt to "prescribe the cure".

The soundness of Dr. Casida's work has earned the respect of other investigators in his field, not only in this country but throughout the world. He has participated in several national and international symposia dealing with various aspects of reproduction. He received the Borden Award in Dairy Production of the American Dairy Science Association in 1954.

In addition to his direct contribution through his own research, Dr. Casida has made another great contribution through his students. He has served as sole or joint major professor for 27 students who have received the Ph.D. degree. In addition he has had many students who earned the M.S. degree and has served on the committees of many more. Most of his students are active in research, and the soundness and high quality of their training under his guidance is reflected in the caliber of their own independent work.

In addition to his ambitious and productive research and teaching program Dr. Casida has probably contributed as much to our Society as any other man. For six years he served as Editor of the Journal of Animal Science and in this capacity contributed much to the esteem and prestige this publication now enjoys in the field of animal science. In addition he has served as Vice-President and as President of our Society.

L. E. Casida

L. E. Casida received the 14th Morrison Award which was presented at the 51st Annual Meeting of the American Society of Animal Production on November 27, 1959.

AMERICAN FEED MANUFACTURERS' ASSOCIATION AWARD

1959

The recipient of the 1959 American Feed Manufacturers' Association Award is a man who has shown unusual scientific ability in research in many aspects of basic nutritional problems. These studies have been concerned with utilization of energy, protein, non-protein nitrogen and mineral compounds. Much of his research has found ready application in practical animal nutrition. This record of research is reflected in some 26 scientific papers published during the past three years with the recipient as author or co-author.

Allen D. Tillman was born June 9, 1916, and was reared on a farm near Rayville, Louisiana. He attended Southwestern Louisiana Institute, Louisiana State University and Pennsylvania State University, majoring in Animal Nutrition and Biochemistry, and was awarded the B.S., M.S. and Ph.D. degrees respectively, from these institutions.

In his research Dr. Tillman has emphasized the improved utlization of low quality roughage when supplemented with certain inorganic elements found in the ash of certain legume hays and protein supplements. This work has led to use of semi-purified diets for ruminant animals. He early recognized the value of radioactive isotopes and has made use of isotope techniques in studying the utilization and availability of phosphorus compounds.

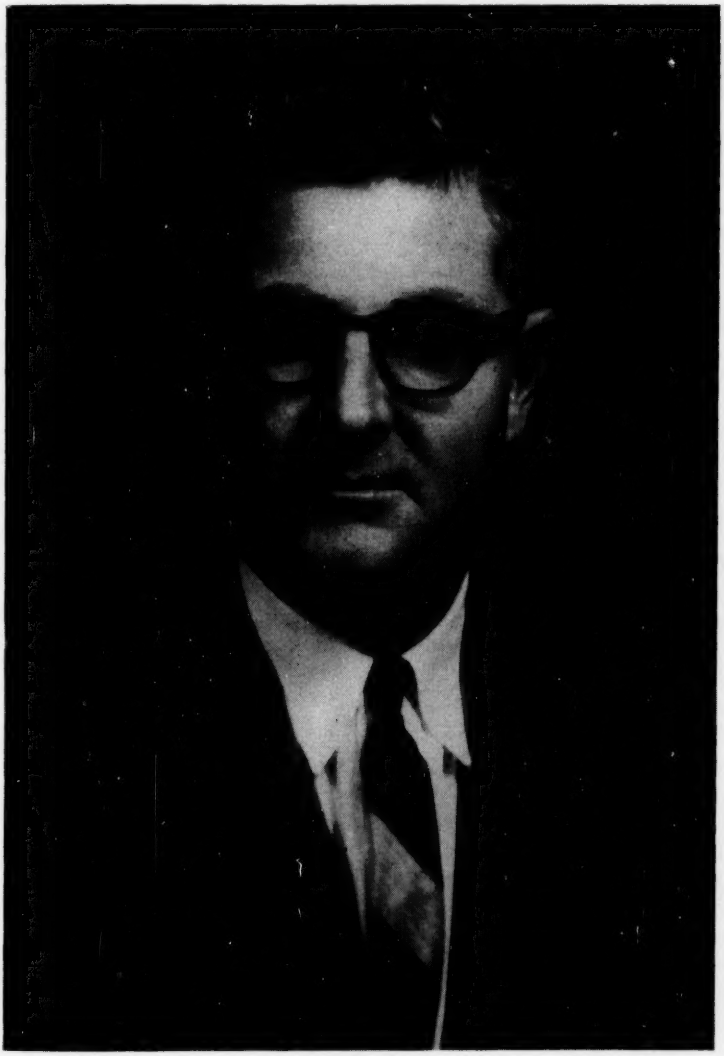
In his studies of nutrient utilization by ruminants he has investigated the influence of estrogenic substances on the absorption and utilization of calcium and phosphorus, the role of fat in mineral utilization, the effect of processing on the nutritional value of cottonseed meal protein and the role of factors which influence the utilization of urea and ammoniated industrial by-products by cattle and sheep.

Dr. Tillman has served at Louisiana State University both as a graduate assistant 1940–42, and as Assistant Professor 1948–52. At Pennsylvania State University he was Instructor from 1946–48. In 1952 he joined the staff of Oklahoma State University where he is currently serving as Professor of Animal Husbandry. During the war Dr. Tillman served both with the army in the Chemical Warfare Service from 1942 to 1944, and in the navy from 1944 to 1946.

In 1956 Dr. Tillman took leave from Oklahoma to serve as a research participant at the Oak Ridge Institute of Nuclear Studies and this led to his appointment as Biological Consultant for the Radiations Laboratory at Oklahoma State University and his selection as General Chairman of the Fourth Conference on Isotopes in Agriculture, sponsored by the Associated Midwest Universities and the Argonne National Laboratories, which was held at Oklahoma State University.

Dr. Tillman was selected as a member of the Animal Husbandry Exchange Team sponsored by the U. S. Department of Agriculture, and in the summer of 1959 visited research institutes and collective farms concerned with animal production in the U.S.S.R.

It is a distinct pleasure to present to you Dr. Allen Douglas Tillman, an outstanding teacher, a respected colleague, a devoted investigator, and an outstanding citizen, as the recipient of the 1959 American Feed Manufacturer's Association Award in livestock nutrition.



A. D. Tillman

Allen D. Tillman received the 12th American Feed Manufacturers' Association Award, which was presented during the 51st Annual Meeting of the American Society of Animal Production in Chicago on November 27, 1959.

H. G. Russell

H. G. Russell received the 1st American Society of Animal Production Extension Award, which was presented during the 51st Annual Meeting of the American Society of Animal Production in Chicago on November 27, 1959.

AMERICA SOCIETY OF ANIMAL PRODUCTION EXTENSION AWARD

1959

Harry Gould Russell was born on a livestock farm in Bureau County, Illinois, in 1909. He graduated from the University of Illinois in 1930 and received the Master of Science degree from the same institution in 1933. During his undergraduate career he was a member of the Livestock, Meats, and Dairy Judging Teams—one of the few men who have been members of all three teams at that institution.

From 1933 to 1936 he worked as a Farm Management and Rural Appraisal Fieldman for a professional farm management organization in western Illinois. In 1936, he returned to the University of Illinois as Livestock Specialist, the position he occupies today.

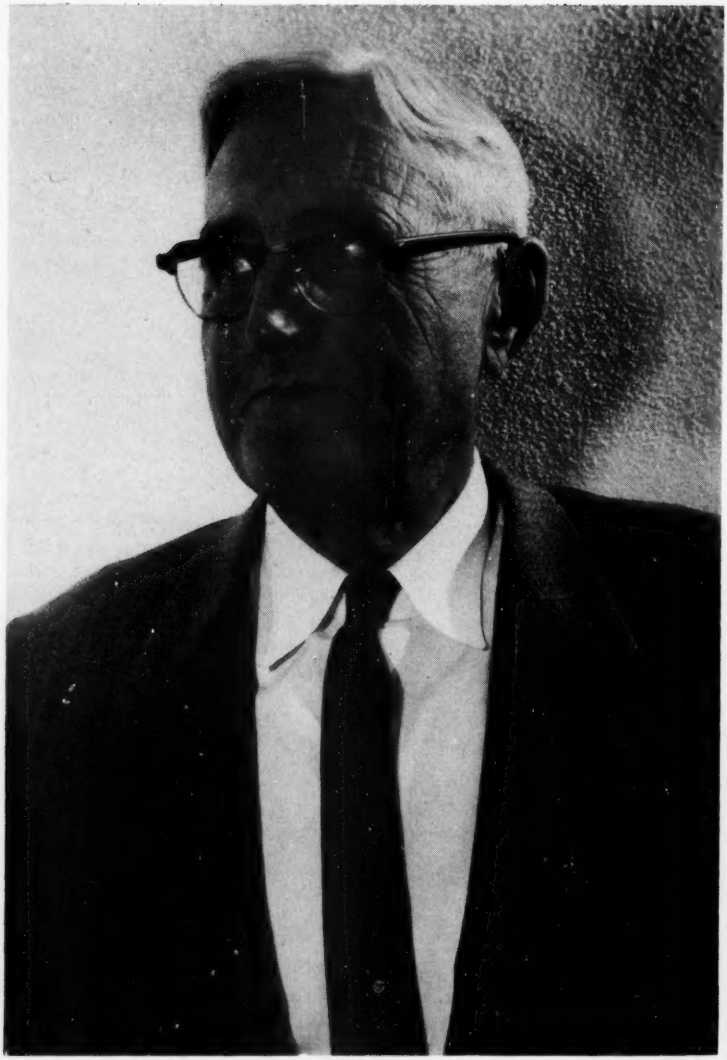
The activities and record of the recipient of the Extension Award for 1959 are unique because he is truly a Livestock Specialist, working with all species of animals in the meat animal field. This is in contrast to the more commonplace procedure where a specialist is responsible for and interested in but one species of livestock.

Harry Russell is held in high regard by both purebred and commercial livestock producers, not only in Illinois but across the United States. His activities with purebred breeders include judging major shows from Georgia to California, serving on Type Standardization Committees of major breeds of all three species of livestock, and helping develop certification programs now in use by all swine breeds. Within Illinois, he helped organize the Illinois Purebred Sheep Breeders' Association, and the Illinois Swine Herd Improvement Association. With his advice and counsel the latter organization sponsored the first boar testing station in the United States.

His activities with commercial producers include the development of performance testing programs for beef cattle, sheep, and "on-the-farm" selection programs for commercial swine producers. He has also recognized the need for expanded marketing programs, assisting in the organization of successful cooperative feeder calf sales, feeder pig sales, lamb pools and wool pools in Illinois. He recognized the need for changes in swine type at an early date and under his guidance, swine type schools and carcass demonstrations have been held in 66 counties and all the major markets in Illinois. He has made good use of mass communication media. During the past few years he has helped with the preparation of three movies. He has also established a system of monthly and quarterly news releases to news outlets in the state. His cattle and hog feeding leaflets established in 1945 and revised yearly have proven to be among the most popular extension publications in Illinois.

He has served as charman, vice-chairman and secretary of the Extension Section of the American Society of Animal Production. He served on the Editorial Board of the Journal of Animal Science from 1947 to 1950.

Among his greatest abilities are his sound judgment, his ability to inspire his co-workers, and his consideration for and loyalty to those who work with him. He has been sound in his choice of programs and successful in their presentation, resulting in widespread acceptance of his teaching. He knows how to work with people and is equally at home with the research worker and the feedlot operator, the businessman interested in livestock and the small operator of the poorer farms in the state.



J. H. Knox

John H. Knox received the 1st American Society of Animal Production Teacher Award, which was presented during the 51st Annual Meeting of the American Society of Animal Production in Chicago on November 27, 1959.

AMERICAN SOCIETY OF ANIMAL PRODUCTION TEACHER AWARD

1959

The recipient of the first Distinguished Teacher Award to be offered by the American Society of Animal Production is an outstanding educator of both young people and adults.

John Harvey Knox was born September 10, 1898, on a livestock farm near Chagrin Falls in northeastern Ohio. He was the youngest of seven children of the late Mr. and Mrs. Ransom Knox.

After public schooling at Auburn township, Ohio, Knox enrolled in animal husbandry at Ohio State Univeristy, where he was graduated four years later, in 1921, with a B.S. degree. At Ohio State he studied under such inspiring professors of animal husbandry as D. J. Kays, Charles Plumb, and Dr. Carl Gay.

In the fall of 1921, after a summer's employment with the Ohio State Extension Service, Knox began graduate study at the University of Illinois. He served as an assistant in the animal husbandry department there until 1924, when he received his M.S. degree, and then was appointed Instructor on the Illinois staff.

The call of the West brought Knox to Texas A & M College in 1927 as Assistant Professor in charge of beef cattle, teaching division. He was appointed Associate Professor in 1928 and remained in that position until 1935, when he was selected to head the animal husbandry department at New Mexico State University. He married Frances Eda George at Grinnell, Iowa, in 1928. They are the parents of two daughters, Carolyn and Irene, and have three grandchildren.

His chief reason for accepting the headship at New Mexico State was that he would be able to conduct research for the Agricultural Experiment Station to vitalize his teaching. Another reason for his choice was the 63,000-acre experimental ranch which is owned and operated by New Mexico State University to enhance teaching and research. In the 24 years that Professor Knox has been at New Mexico State, he has never regretted his choice of a combined teaching-research career.

As an active member of the American Society of Animal Production, Mr. Knox has served in various capacities including membership on the Executive Committee and President of the western section from 1942 to 1946.

He is also a member of the American Association of University Professors, the New Mexico Education Association, the National Education Association, Alpha Zeta, Sigma Xi, and the New Mexico Cattle Growers Association. He is the author of numerous Experiment Station bulletins, press bulletins, research reports, and journal articles.

Professor Knox is a masterful teacher. In classroom or in informal discussions and conversations, he is ready and capable of exploring the many facets of a complex field, being quite at home discussing nutrition, genetics, judging, selection and record keeping, or the more mechanical skills of fitting, training, showing and herdsmanship.

He translates research into terms of useful practice, and even more important, by the manner in which he presents results, he motivates his listeners to learn to evaluate research so they can apply future findings to their ranch or farm operations. The same qualities that enable him to be a master teacher in the classroom and laboratory have also made him popular as a speaker for livestock meetings not only in New Mexico but over the nation.

Freshmen get off to a good start in their animal husbandry study at New Mexico State University, for the introductory animal husbandry course has been taught continuously by Professor Knox for the 39 years of his teaching career. Two of his other favorite courses are Range Beef Production and Breeds of Livestock. He has also taught courses in principles of feeding, livestock judging, market classes and grades of livestock, animal nutrition, and swine production.

Professor Knox shoulders a heavy share of the student advising load and willingly takes time to assist students with any of their problems. He actively sponsors the Block and Bridle Club and gives strongest support to the university judging teams. Similarly he utilizes all departmental resources in conducting judging contests for freshmen, 4-H club, and Future Farmers of America groups. The fact that students and colleagues feel free to consult with Professor Knox and that graduates make special efforts to visit with him on return to the campus indicates the regard in which he is held. The high percentage of his students who have been successful in graduate work in animal husbandry and related fields speaks well for his ability to stimulate and motivate students to continued endeavor.

In gaining the admiration and respect of cattlemen in New Mexico and throughout the nation, John H. Knox carries his teaching beyond the classroom. He organized annual Feeders' Day and Ranch Day programs as early as 1936 to present research findings to livestock people. During the past four years he has conducted an annual Cattle Breeders' School for the New Mexico Cattle Growers' Association with programs on nutrition, breeding, diseases, and range management. These activities are highly regarded by livestock people for their educational value. Professor Knox was selected as Cattleman of the Year in 1954 by the New Mexico Cattle Growers' Association for excellence in teaching and training livestock people. This is the only instance in which an educator and research man has been so honored by the Association. In addition, his research work in animal nutrition and livestock improvement has returned literally millions of dollars to the cattlemen of the state and nation.

Professor Knox is a warm and friendly person. Whether he is lecturing in the classroom or conversing in the home, on the range or in a hotel lobby, he inspires his listeners to do greater and better things with livestock. His example of honesty, integrity, hard work, and kindness—coupled with understanding—makes him admired as a most distinguished teacher, not only of students, but also of farm and ranch people.

FELLOWS OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

In recognition of distinguished service over a period of 25 years or more, the title of Fellow has been conferred upon the following men:

Roland M. Bethke. Dr. Bethke was born in Elkhart Lake, Wisconsin. He received his B.S., M.S., and Ph.D. degrees from the University of Wisconsin. After three years at that Institution, he joined the staff of the Ohio Agricultural Experiment Station. During 1923 to 1948 he was in charge of nutritional investigations, Assistant Director of the Station, and Chairman of the Animal Science Department. Dr. Bethke became Vice-President and Director of Research of the Ralston Purina Company in 1948. He has received the Borden Award in nutrition. Dr. Bethke has been Secretary, Vice-President and President of the Society, Vice-President and President of the Institute of Nutrition, and Vice-President and President of the Poultry Science Association. He is a leader in the field of animal nutrition.

Gustav Bohstedt. Dr. Bohstedt was born in Germany. He received his B.S., M.S., and Ph.D. degrees from the University of Wisconsin. After a year at Iowa State College, he became Instructor and Assistant Professor at Wisconsin during 1917–1921. He was appointed Chief of the Department of Animal Industry at the Ohio Agricultural Experiment Station in 1921, and he returned to Wisconsin in 1924 as Professor of Animal Husbandry and later was Chairman of the Department. Dr. Bohstedt received the Morrison Award in 1949 and was honor guest to the Saddle and Sirloin Club in 1951. He has been Secretary, Vice-President and President of the Society. Dr. Bohstedt is a leader in animal nutrition and has published extensively in both basic and applied fields.

William A. Craft. Dr. Craft was born in Jonesboro, Arkansas. He received his B.S. and M.S. degrees from Iowa State College and his Ph.D. from the University of Wisconsin. From 1923 to 1936 he was Assistant and Associate Professor at the Oklahoma State University. He was appointed in charge of Swine Investigations, B.A.I., U.S.D.A. in 1936 and Director of the Regional Swine Breeding Laboratory in 1937. Dr. Craft has been

Vice-President and President of this Society. He has published extensively in the fields of genetics and animal breeding. He has had a significant effect on genetic research and has pioneered in the development of patterns of Federal and state and inter-state cooperation in doing research on a large and decentralized basis.

Albert E. Darlow. Dr. Darlow was born in Stillwater, Oklahoma. He received his B.S. and M.S. degrees from the Oklahoma State University and his Ph.D. degree from the University of Wisconsin. Dr. Darlow rose from Instructor to Professor at Oklahoma State during the years 1919–1935. He then moved to Wisconsin, becoming Chairman of the Animal Husbandry Department in 1938. In 1943 he returned to Oklahoma as Chairman of the Department. Later he became Dean of Agriculture and Vice-President for Agricultural Sciences. Dr. Darlow has published in the fields of physiology, reproduction and nutrition, and he is well known as a judge of livestock. He has been Vice-President and President of the Society, and was Honor Guest in 1958. He has contributed to the development of a closer working relationship among members of the livestock industry.

Albert G. Hogan. Dr. Hogan was born in Maryville, Missouri. He received his A.B., B.S., and M.A. degrees from the University of Missouri and his Ph.D. degree from Yale University. He was Assistant Professor and Associate Professor of Chemistry at Kansas State College during 1914–1919. He then became Professor of Animal Nutrition and later Chairman of the Department of Agricultural Chemistry at the University of Missouri. Dr. Hogan has been a recipient of the following awards in nutrition: Mead Johnson and Company, Morrison, Borden, and Osborne and Mendel. He was made an Honorary Fellow in the American Institute of Nutrition in 1959. Dr. Hogan has pioneered in the problem of the nutrition of the whole life cycle and has been instrumental in discovering and identifying several vitamins.

Wenzel L. Stangel. Dr. Stangel was born in Stangelville, Wisconsin. He received his B.S. degree from the Agricultural and Mechanical College of Texas, M.S. degree from the University of Missouri, and an Honorary LL.D. degree from Texas A & M College. Dr. Stangel rose from Instructor to Professor at the Texas A & M College during the years of 1916–1925. He was then appointed Professor and Head of the Department of Animal Husbandry at the Texas Technological College. He became Dean of the College of Agriculture at that institution in 1949. Dr. Stangel's interests have been broad but mainly in the areas of beef cattle and sheep. He has been very active in livestock shows and has an international reputation as a judge.

Kenneth F. Warner. Dr. Warner was born in Roca, Nebraska. He rereceived his A.B. and Honorary Doctor of Agriculture degree from the

University of Nebraska, and M.S. degree from the University of Minnesota. Dr. Warner spent most of 1915–1921 as Extension Animal Husbandman at the University of Nebraska. From 1921 to 1957, he did research and extension work in meats and training work with the Federal Extension Service and the Foreign Agricultural Service of the U.S.D.A. He received the Superior Service Award from the U.S.D.A. and the Signal Service Award from the Reciprocal Meat Conference. Dr. Warner pioneered in the use of carcasses and meat to demonstrate the effect of breeding and feeding practices, and in the development of teaching methods adapted to extension.

Arthur D. Weber. Dr. Weber was born in Muscotah, Kansas. He received the B.S. and M.S. degrees from Kansas State College and his Ph.D. degree and Honorary D.Sc. degree from Purdue University. Dr. Weber was on the staffs of Kansas State College from 1924 to 1926 and the University of Nebraska from 1926 to 1931. He then went to Kansas State College as Professor of Animal Husbandry and has since risen from Head of the Department to Dean and Director of the College of Agriculture. Dr. Weber has been Secretary, Vice-President and President of this Society. He was honor guest to the Saddle and Sirloin Club in 1952. Dr. Weber is well known as a teacher, research worker and administrator and has an international reputation as an expert judge of livestock.

MEMORIALS

N. N. Allen

Nathaniel N. Allen, Professor of Dairy Husbandry at the University of Wisconsin, died suddenly March 7, 1959, from a heart attack. His untimely passing is a deep-felt loss. Through his publications he was nationally known and appreciated. He served as Director and Vice-President of the American Dairy Science Association. His unusual ability to interpret research findings in terms of practical application distinguished him to dairymen throughout the nation as a "farmers' nutritionist".

He was born at Keytesville, Missouri, August 28, 1901. He received the B.S. degree from the University of Missouri in 1929 and the Ph.D. degree at the University of Minnesota in 1935. He served on the Minnesota faculty until 1942 and was then at the University of Vermont until 1945 when he came to Wisconsin.

At Minnesota, while conducting basic research on factors influencing fat levels in blood and milk, he developed a standard test for fat analysis in blood. More recently his research has emphasized the importance of the physical status of the ration on rumen physiology.

He was "at home" when teaching whether it be a graduate class or seminar, an undergraduate course, a short course class, or a meeting of dairy farmers. His homespun illustrations clarified many an involved problem. Nat Allen loved the outdoors. He was a generous man with deep interest in community affairs. He belonged to the Acacia, Alpha Zeta, Gamma Sigma Delta, and Sigma Xi fraternities. He also was a member of the First Baptist Church in Madison.

He was married to Mildred Wisner at Hannibal, Missouri, in 1930. Surviving are his wife; three daughters, Mrs. Joseph Cattellino, Saxon, Wisconsin; and Virginia and Sarah, both at home; three sons, James, Aberdeen, South Dakota; Edward, Minneapolis, Minnesota; and David, at home.

William Brown Connell

William Brown Connell, Extension Livestock Specialist, who retired in 1951 after 33 years with the Pennsylvania State University, died at the age of 73 in the Centre County Hospital, May 26, 1959 after a long illness. Born March 13, 1886 at Edinboro, Pennsylvania, Connell was reared on a livestock farm where Percherons, Shropshires, Poland Chinas and Shorthorns were raised. He graduated in 1910 from the Edinboro State Normal School and was a school principal for four years. He graduated from Penn State in 1918 and was Extension Livestock Specialist until he retired in 1951. He was particularly interested in sheep husbandry and initiated in 1919 the cooperative wool market project. He served as Secretary of the Pennsylvania Sheep and Wool Growers Association, as Secretary of the Pennsylvania Livestock Breeders Association, and as Secretary and President of the Extension Section of the American Society of Animal Production. He was a member of Epsilon Sigma Phi, honorary extension fraternity. Following retirement Mr. Connell continued to be active in livestock circles as fieldman for the Pennsylvania Shorthorn Breeders Association.

Mr. Connell is survived by his widow, the former Nell Clogston, who is an assistant 4-H Club leader, and a daughter, Mary Ellen, a sophomore at Penn State.

George H. Hart

With the passing of George Hart, animal husbandry lost one of the great pioneers who truly laid the foundation of modern animal science. George Hart was one of the

rare individuals who combines the qualities of a talented scientific investigator, an outstanding administrator, a born leader of men, and a vigorous and kindly human being. Possibly his greatest attribute was his ability to encourage and inspire young men.

George Hart was born in Philadelphia in 1883. He was awarded a doctor's degree in veterinary medicine at the University of Pennsylvania in 1903, and an M.D. at George Washington University in 1908. In 1910 he moved to California to investigate Texas cattle fever and other diseases for the Bureau of Animal Industry. The move was beneficial both to him and to California where he lived for the next half century.

Following his graduation from the University of Pennsylvania, he served as Bacteriologist and Pathologist, Bureau of Animal Industry, U. S. Department of Agriculture, for five years. He was City Veterinarian for Los Angeles from 1910 to 1917 and then joined the faculty of the College of Agriculture of the University of California at Davis, where he spent the rest of his life. Here he organized the Department of Animal Husbandry which he headed for twenty-two years, during which period he made outstanding contributions in animal nutrition and endocrinology, particularly in the fields of vitamin A and gonadotropic hormones. He was also instrumental in building the faculty of his Department with a number of outstanding scientists whose names are familiar to the members of the Society of Animal Production, including Harold Cole, Harold Goss, Paul Gregory, Harold Guilbert, Carroll Howell, Elmer Hughes, Max Kleiber, Sylvester Mead, Robert Miller, James Wilson, and many others.

At the normal retirement age of 65 he became Dean of the newly organized School of Veterinary Medicine of the University of California and played a leading part in the design and construction of the large new building at Davis which houses this school. He retired officially in 1954, as Dean Emeritus, still filled with energy and enthusiasm.

Dr. Hart's first wife Eva Cadman Hart, to whom he was married for forty years, died in 1949 after a long illness and he married Mrs. Theresa Dennis in 1954. Following his retirement, the years of his second marriage were very happy ones and gave him time to follow some of his numerous outside interests.

George was an expert and avid fisherman and hunter. In the academic world, his influence was wide. His advice was sought on many matters affecting the University of California on its several campuses. He was President of the American Society of Animal Production in 1939, and his portrait was hung in 1947 in the Saddle and Sirloin Club at the Union Stockyards, Chicago. He will be long remembered by his many friends who came to him for counsel and help which he unfailingly gave throughout the years.

William Howard Hough

William (Bill) Howard Hough was born in Chesterville, Ontario, in 1925 and died June 6, 1959 at Mile 1019, Yukon Territory where he was Superintendent of the Whitehorse Experimental Farm of the Canadian Department of Agriculture. Bill was an ardent sportsman and this led to his untimely death through drowning on a fishing expedition.

He graduated with a Bachelor of Science Degree from Ontario Agricultural College in 1951 and joined the staff of the Animal Husbandry Division, Central Experimental Farm, Ottawa, to do sheep production research. His interest in physiology led him to Cornell University from which he received a Master of Science Degree in 1954, after which he returned to Ottawa. In 1956 he was appointed as Superintendent of the pioneer Experimental Farm at Mile 1019 on the Alaska highway, about 100 miles west of Whitehorse.

Hough is survived by his wife and two children.

Lawrence A. Kauffman

Lawrence A. Kauffman, Professor of Animal Science and former Chairman of the Department of Animal Science at The Ohio State University, passed away on June 18, 1959. Professor Kauffman had been in failing health for several months.

He was born in Dayton, Ohio, in 1898. He received a B.S. degree in Agriculture from Ohio State University in 1920, and the M.S. degree from Iowa State College in 1928. He was County Agricultural Agent in Jackson County, Ohio, from 1920 to 1924 and Livestock Specialist on the State Extension staff from 1924 to 1933.

In 1933, Mr. Kauffman left the University to become Executive Secretary of the Ohio Wool Growers Co-operative Association. During the twelve years he was with this wool marketing association, he became well known as an authority on wool and served as a member of the National Wool Merchandising Advisory Committee for the Commodity Credit Corporation. Professor Kauffman helped organize the American Sheep Producers Council and was a member of its Board of Directors. He was the executive secretary of the Ohio Council of Farm Co-operatives from 1945 to 1947. During this same period, he was President of the Ohio Council of Agricultural Research and a director of the National Council of Farmer Co-operatives.

In 1947 he returned to Ohio State University as Professor of Animal Science. He was one of the outstanding teachers in the College of Agriculture. In 1955, the students of the College honored him by naming him a Professor of the Year.

On July 1, 1955, Professor Kauffman was appointed Chairman of the Department of Animal Science at Ohio State University and at the Ohio Agricultural Experiment Station. In addition to his departmental teaching, research and administrative duties, he was extremely active in College of Agriculture and in University affairs. Such activities included membership on the Faculty Council, University Planning Committees, Conference Committee of the teaching staff, and the Advisor Committee to the President and the Board of Trustees. His was a lifetime of service to agriculture in its many facets—education, research and business.

Professor Kauffman is survived by his wife, Firme, his daughter Nancy (Mrs. Marshall Mowrey), and three grandchildren.

Joseph M. Vial

Joseph M. Vial, 70, prominent for many years in the fields of animal husbandry and extension service education in Maryland and a number of other states, died Tuesday, February 24, 1959 of a sudden heart attack at his home in University Park, Maryland.

As a University of Maryland Extension Livestock Specialist for 20 years, he worked principally with producers of beef cattle and horses, but he assisted frequently with the swine, sheep and 4-H programs. He did much to stimulate and improve the livestock industry in Maryland. He was Secretary of the Eastern National Livestock Show from its inception in 1947 until he retired from the University of Maryland in 1954. Then he was manager of the show which is one of the largest in the East and one of the four largest in the United States.

Professor Vial was a native of LaGrange, Illinois and a 1912 graduate of the University of Illinois. He was an artillery veteran of World War I. After graduating from college, he farmed for a number of years in Northwest Iowa. He was active in organizing the Iowa Farm Bureau Federation, and was instrumental in the expansion of the livestock extension program in Iowa as well as in Illinois, Pennsylvania and Maryland. He was invited by the Extension Directors of New York and Maine to assist in extension teaching programs in livestock.

He served as a National Director of the Percheron Horse Breed Registry Association and was widely sought as a judge of national and international horse shows, including the Chicago International. His judgment in all phases of livestock production was

widely accepted and he placed fat and breeding classes at the state level in nearly all eastern and most midwestern states. He was actively associated with the Maryland Purebred Beef Cattle Breed association, serving as Secretary of the State Angus, Hereford and Shorthorn Breed associations for a number of years.

Mr. Vial was an Honorary Fellow in the American Society of Animal Production of which he had been a member for 35 years. He was the author of numerous publications and articles on animal husbandry, and appeared on farmer's week programs at the Ohio, Massachusetts, Connecticut and other colleges of agriculture.

He was an elder of Riverdale Presbyterian Church in University Park, Maryland. Surviving are his wife, Ruth M. Vial; two daughters, Mrs. Frederick T. Battey, LaGrange, Illinois; and Mrs. Lester E. Hogue, Queenstown, Maryland; two sons, Dr. Theodore M. Vial, Princeton, New Jersey; and Peter F. Vial, Silver Spring, Maryland.

Edward N. Wentworth

Edward Norris Wentworth was born at Dover, New Hampshire, January 11, 1887 and died April 21, 1959. During his boyhood, he lived at State Center, Iowa. He received the Bachelor's Degree at Iowa State College in 1907, the Master's Degree in 1909, and the honorary degree, Doctor of Agriculture, in 1951. Also for short periods he studied at Cornell and at Harvard. He was on the staff of the Animal Husbandry Department at Iowa State College from 1907 to 1913 and was Professor of Animal Breeding at Kansas State Agricultural College from 1914 to 1917. He was Associate Editor of the Breeders' Gazette and taught animal husbandry in the Chicago Veterinary College from 1913 until 1914. He went to the first officers training camp in 1917, saw service as a Captain and Major in France and Germany, and rose later to the rank of Colonel in the reserve. He was Assistant Director of the College of Agriculture and Professor of Animal Husbandry at the AEF University at Beaune in France in 1919. On returning from Euproe in 1919, he joined the staff of Armour & Company where he was director of the Livestock Bureau until his retirement.

All his life he maintained a lively interest in genetics and animal breeding and stimulated many others to special efforts in these and related fields of animal husbandry. He was especially interested in the history of the livestock industry and of the men who played prominent parts in that. He was the author or co-author of many articles and of several books, such as: "Shepherds Empire", "America's Sheep Trails", "From Cave to Cornbelt", and "Cattle and Men". He was an Honorary Fellow of the American Society of Animal Production.

For many years he superintended the horse shows at the International Livestock Exposition. He also served in various ways at many other livestock shows. He was widely known all over the United States and was a familiar figure at meetings and conventions of stockmen and their associations.

CHAIRMEN OF COMMITTEES, PROGRAM CHAIRMEN AND SPECIAL ASSIGNMENTS FOR 1960

Standing Committees

Committee on Research ..... O. D. Butler
Committee on Monograph ..... C. E. Terrill
Committee on Extension ..... H. H. Mayo
Committee on Membership ..... H. H. Stonaker
Committee on Teaching ..... G. L. Robertson

Special Committees

Committee on Information ..... C. F. Neumann
Committee on Necrology ..... W. D. Salmon
Committee on Nominations ..... W. M. Beeson
Committee on Morrison Award ..... H. H. Stonaker
Committee on American Feed Manufacturers Award ..... O. B. Ross
Committee on Registration and Facilities ..... G. D. Pendergrass
Committee on Resolutions ..... W. Gifford
Committee on Fellows ..... M. E. Ensminger
Committee on Extension Award ..... W. P. Garrigus
Committee on Special Grants for
Foreign Travel and Study ..... J. O. Grandstaff
Committee on Teaching Award ..... W. W. Green

Program Committees

Breeding and Genetics ..... V. A. Garwood
Meats ..... C. O. Schoonover
Nutrition ..... J. A. Hoefer
Pastures and Forages ..... W. W. Heinemann
Physiology ..... A. M. Sorenson

Special Representatives

American Association for Advancement of Science Council ..... T. C. Byerly
Committee on Intersociety Cooperation and
Scientific Manpower Commission ..... J. E. Foster
Division of Biology and Agriculture,
National Research Institute ..... C. F. Sierk
European Association for Animal Production ..... N. R. Joshi
Ralston Purina Award Committee ..... L. E. Hanson
Pasture and Forage Crop Improvement Committee ..... W. B. Anthony

NEWS AND NOTES

The North Atlantic Section of the Society will hold its annual meeting at the University of Massachusetts, Amherst, August 23–24, 1960.

Techniques and Procedures in Animal Production Research, a monograph prepared by the Society's Committee with C. E. Terrill as chairman, has been completed and negotiations for its publication under the general editorship of A. B. Chapman are under way. Further announcements will be made in News and Notes as soon as the monograph becomes available.

The National Science Foundation announces that the next closing date for receipt of proposals for support of renovation and/or construction of graduate level (doctoral) research laboratories is March 1, 1960. Proposals received prior to that date will be reviewed during late spring and early summer. Disposition of approved proposals will be made during late summer 1960. Proposals received after the March 1, 1960 closing date will be reviewed following the next closing date which is expected to be September 1, 1960.

This program will continue to require at least 50% participation by the institution with funds derived from non-Federal sources. Proposals may be submitted for modernization or construction of research laboratories, including laboratory furnishings but not including apparatus or equipment, in any field of the natural sciences. For the present, this program is restricted to those departments which have an on-going program leading to the Ph.D. degree. Support of facilities to be used primarily for instructional purposes will not be considered. It is suggested that, depending on the discipline involved, preliminary inquiry be made to either the Division of Biological and Medical Sciences or the Division of Mathematical, Physical, and Engineering Sciences, National Science Foundation, Washington 25, D. C. Information concerning the Program and instructions for preparation of proposals may be obtained upon request.

Notice of Revised Indirect Cost Policy for Research Grants. In connection with its programs for the support of basic research, the National Science Foundation for some years has followed the policy of permitting institutions to apply for and receive, as an indirect cost allowance, up to 15% of the total direct costs involved in approved grant proposals. Because of rising costs of administration and the adverse effect of such increases upon the ability of institutions to carry on research work, the Foundation has made a revision in its indirect cost policy. Pending completion of a study of the entire problem of indirect costs, the Foundation herewith announces that, effective January 1, 1960, it will permit institutions to request up to 20% of total direct costs as the allowance for indirect costs in research proposals. In no event, however, may such indirect costs exceed the last "audited" or "negotiated" rate approved for the institution by a Federal agency for purposes of Government-sponsored research and development. Thus, an institution with an "audited" or "negotiated" indirect cost rate so approved may claim such rate provided it does not exceed 20% of the total direct costs. This announcement will be reflected in the forthcoming revision to the 1955 edition of the National Science Foundation brochure on "Grants for Scientific Research".

Reproductive Physiology and Protein Nutrition, edited by James H. Leathem; 65 pages; $2.00; Rutgers University Press, New Brunswick, N. J., 1959. This book (paper cover) contains the six papers presented at the Fifteenth Annual Protein

Conference of the Bureau of Biological Research, 1959. The first two papers deal specifically with dietary protein and reproduction, studies conducted with male and female laboratory animals being treated separately. Other papers cover such topics as the role of nutrition in mammary physiology, effect of feed level on reproduction in farm animals, hormonal relationships to nutrition in domestic animals, and endocrine changes in undernutrition of human beings. Each paper, although not exhaustive in treatment of subject matter, is supported by some 30–40 references to recent journal articles. The book succeeds in relating certain aspects of endocrinology to nutrition.

Nutritional and Economic Aspects of Feed Utilization by Dairy Cows, edited at Michigan State College by C. R. Hoglund, G. L. Johnson, C. A. Lassiter and L. D. McGilliard; 287 pages; $3.95; Iowa State College Press, Ames, Iowa, 1959. This book is based upon the papers presented at a symposium sponsored by Michigan Agricultural Experiment Station in 1957 for the purpose of bringing together for exchange of ideas a group of agronomists, economists, nutritionists and statisticians concerned with all important areas of research in the feeding of dairy cattle. Twenty-six authors contribute to the 22 papers which have been so grouped as to divide the book into seven logical parts covering such subjects among others as Adequacy of Dairy Feeding Input—Output Research Data, Nutritional Considerations, Designing Feeding Experiments, and Application of Dairy Feeding Efficiency Research Data. Representative references to subject matter are given at the end of several of the papers.

A. G. Hogan has been on the staff of the National Livestock and Meat Board as a Research Consultant since his retirement at the University of Missouri.

R. M. Kottman, Dean, West Virginia College of Agriculture, Forestry and Home Economics, has been named Dean of Agriculture and Home Economics, and Director of the Agricultural Experiment Station of Ohio State University, effective June 1, 1960. Dean Kottman, a native of Iowa, is nationally recognized for his leadership in animal husbandry research dealing with swine heredity and effectiveness of selection in swine breeding.

John E. Foster, Head, Department of Animal Husbandry, Maryland, has been honored with a Life Membership in the Maryland Beef Cattle Producers Association "in recognition of his outstanding services to the livestock producers of the State".

Lanoy Hazel, Department of Animal Husbandry, Iowa State University, spent six weeks in Argentina last fall, under the ICA program, to consult with agricultural officials on immediate problems of economic development.

W. E. Connell, Professor of Animal Husbandry, Colorado State University, returned last August from a four-year assignment at the University of Peshawar, Pakistan, under the CSU–ICA Contract program. Since returning to CSU, Mr. Connell is also serving as Assistant Campus Coordinator for the University of Peshawar Contract.

L. A. Swiger, who recently completed his Ph.D. in animal breeding at Iowa State University, has been appointed Animal Geneticist in the Beef Cattle Research Branch of the Animal Husbandry Research Division, A.R.S., U.S.D.A. He assumed his duties on the Beef Cattle project at Lincoln, Nebraska on December 7.

Earl Ray, Animal Husbandman, Southwest Range and Sheep Breeding Station, Fort Wingate, New Mexico, is now stationed at Las Cruces, New Mexico.

David A. Cramer has joined the staff of the Department of Animal Husbandry, Colorado State University, as specialist in meats. Dr. Cramer recently finished his Ph.D. in nutrition and biochemistry at Oregon State College.

Albert M. Lane, Arizona, Extension Animal Husbandman, has been granted a study leave effective the 16th of September, 1959. While he is away Paul E. Lineberry, a Missouri '52 graduate, will serve as Acting Extension Animal Husbandman—headquarters at Tucson.

Carl E. Lueker was appointed Extension Animal Husbandman in Arkansas, effective September 1, 1959; headquarters at Little Rock. Dr. Lueker recently earned his Ph.D. in animal nutrition at the University of California.

Clarence L. Moore was appointed Area Specialist in Livestock in Hawaii, August 17, 1959; headquarters Kealakekua. His territory will be the five counties on the Island of Hawaii. Dr. Moore is a native of South Dakota and earned his B.S., M.S. and Ph.D. degrees at South Dakota State College.

Neil B. Webb was appointed Extension Specialist in Animal Husbandry, September 1, 1959, East Lansing, Michigan. A native of West Virginia, he received his B.S. degree at West Virginia University, M.S. at the University of Illinois and Ph.D. at Missouri University.

Quin E. Kolb was appointed Extension Animal Husbandman, Madison, Wisconsin, September 1, 1959. He is a native of Wisconsin and a graduate of Wisconsin University. He will be responsible for 4-H livestock project work.

S. H. Work, since 1955, Agricultural Attache to Santiago, Chile, has completed his assignment there and returned to Washington as a member of the Attache Service staff of FAS.

George T. Woods, Extension Veterinarian, Illinois, resigned, August 24, 1959.

Robert H. White, Extension Animal Husbandman in Kentucky, resigned September 20, 1959, to continue work toward his Ph.D. at the University of Kentucky.

Paul E. Howe, retired from the Department of Agriculture, has been appointed Collaborator in the Agriculture Research Service to go to the World Agriculture Fair, New Delhi, India, as Feed Specialist. In April he attended a Symposium on Nutrition in Asian Countries, in Tokyo, and in August conducted a work shop on nutrition in Modern Methods of Institutional Management at the Texas Woman's University.

Richard C. Wahlstrom in charge of swine nutrition, South Dakota State College, has been promoted to Head, Department of Animal Husbandry, effective January 1, 1960. Dr. Wahlstrom received his B.S. from the University of Nebraska and his M.S. and Ph.D. degrees in animal nutrition from the University of Illinois.

Mrs. J. C. Miller passed away on January 7, 1960. Dr. Miller, Head of the Department of Dairy and Animal Husbandry, Corvallis, Oregon, is a past-president of the American Society of Animal Production.

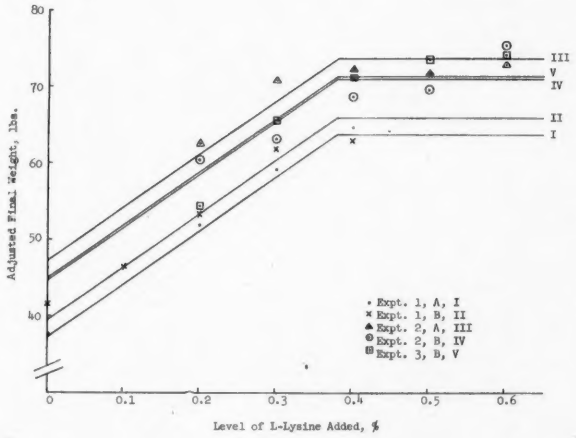
D. E. Becker, University of Illinois, R. H. Dutt, University of Kentucky, K. E. Gregory, University of Nebraska, and R. W. Swift, Pennsylvania State University have accepted appointment to the Editorial Board of the Journal.

Training Program for Steroid Biochemistry. To alleviate the shortage of qualified trained personnel in steroid research, a Training Program will be sponsored by the United States Public Health Service through the National Cancer Institute of the National Institutes of Health. The courses will stress both theoretical and practical aspects as well as specialized laboratory techniques in steroid research.

Post-doctoral candidates (M.D. or Ph.D.) selected for admission both at Worcester and Utah will receive stipends of $5500 for a one-year period. Pre-doctoral candidates (B.S., M.S., or equivalent) selected for admission (only at Worcester) will receive stipends of $1800 for a six-month period. Send inquiries and requests for applications to: Dr. Kristen Eik-Nes, Department of Biochemistry, College of Medicine, University of Utah, Salt Lake City, Utah, or Dr. William R. Nes, Department of Chemistry, Clark University, 950 Main Street, Worcester, Massachusetts. Classes start October 1, 1960. Final data for completion of application: June 1, 1960.

ERRATUM

McWard, G. W., D. E. Becker, H. W. Norton, S. W. Terrill and A. H. Jensen. 1959. The lysine requirement of weanling swine at two levels of dietary protein. J. Animal Sci. 18:1059. The values for adjusted final weight as plotted in figure 1 were incorrectly calculated. The correct values are presented below.



Please paste this over the original figure shown on page 1063.

INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editoral Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. Consult a recent issue for style and form. The following are guides:

   (a) Manuscripts must be typed, double-spaced and the ribbon copy submitted. Submission of two copies (one carbon) will facilitate review.

   (b) All pages, including those of tables and legends, must be numbered. The lines of the text, but not of tabular material or "Literature Cited", must be numbered in the left margin, beginning with one at the top of each page.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data. Each table should be on a separate sheet.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnification of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addresed to the Editor: W. D. Gallup, Department of Biochemistry, Oklahoma State University, Stillwater, Oklahoma, or to the publisher: Boyd Printing Company, Inc., 49 Sheridan Ave., Albany 10, N. Y.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, C. E. Terrill, Animal Husbandry Research Division, Agricultural Research Center, Beltsville, Maryland, or to the publishers, Boyd Printing Company, Inc., 49 Sheridan Avenue, Albany 10, N. Y.